The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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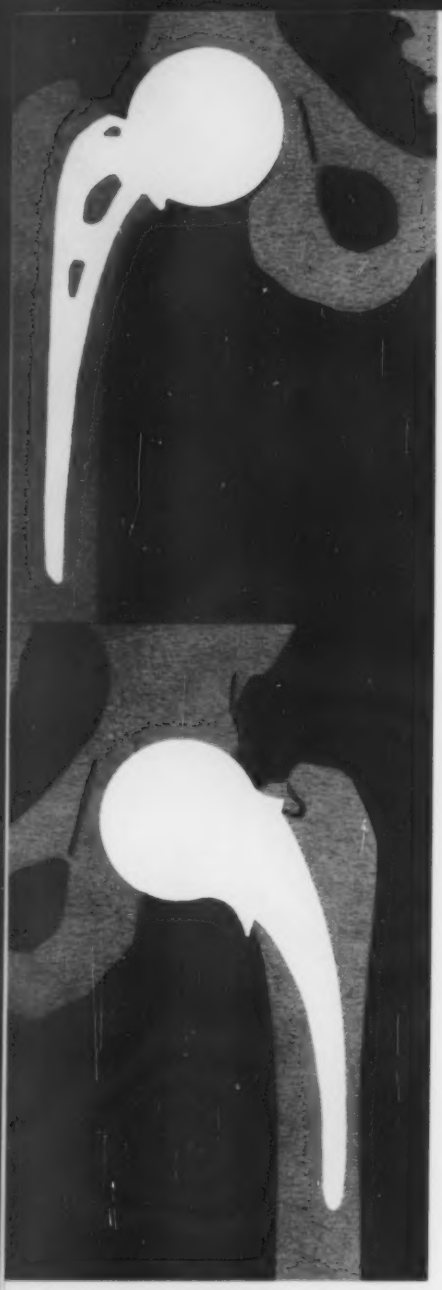

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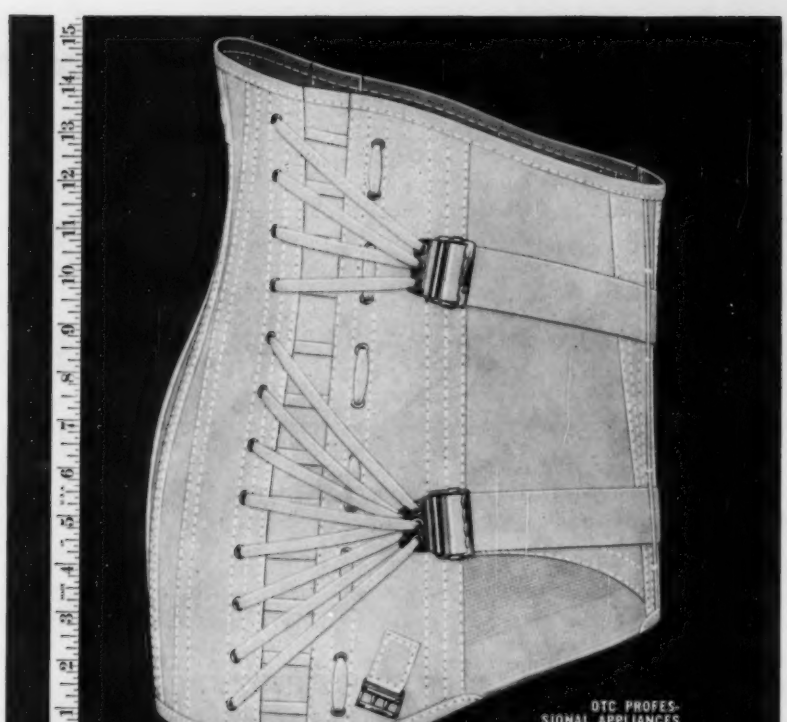

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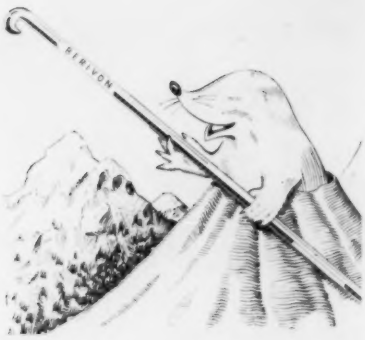

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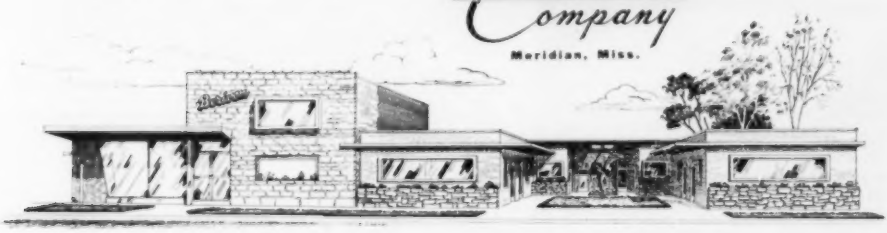

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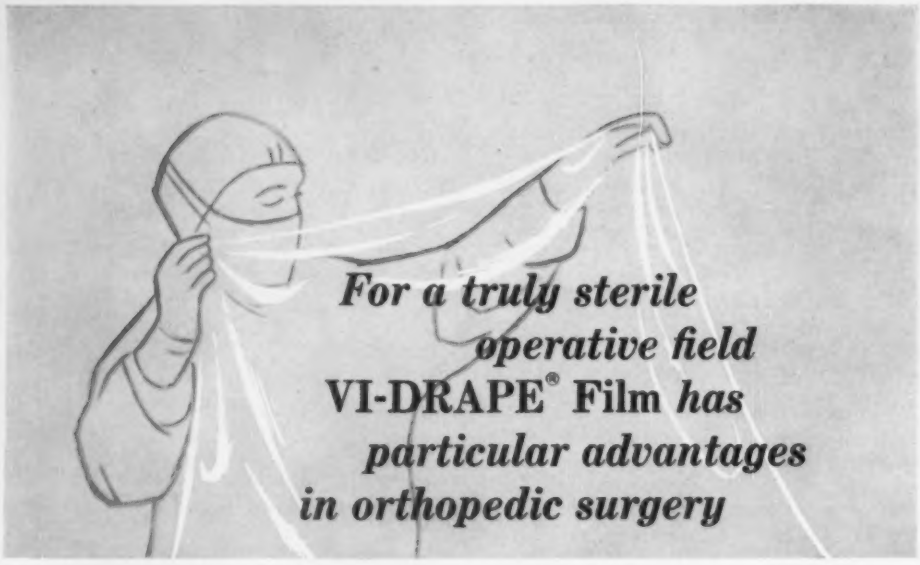

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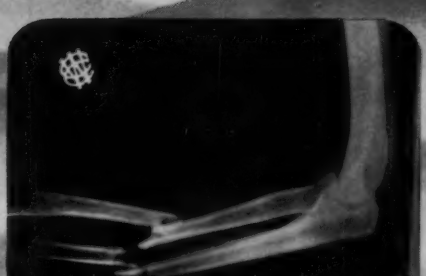

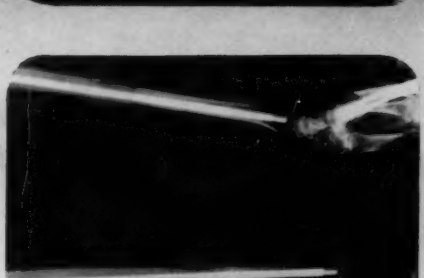

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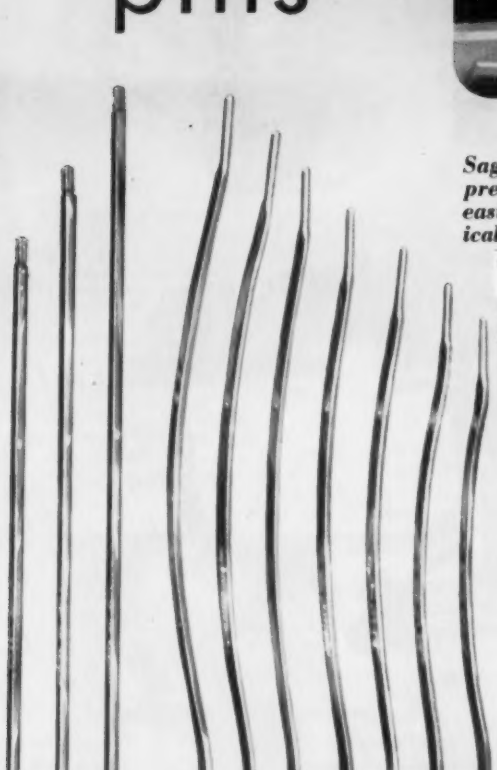

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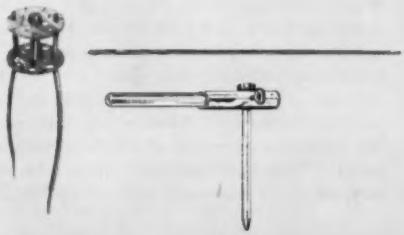

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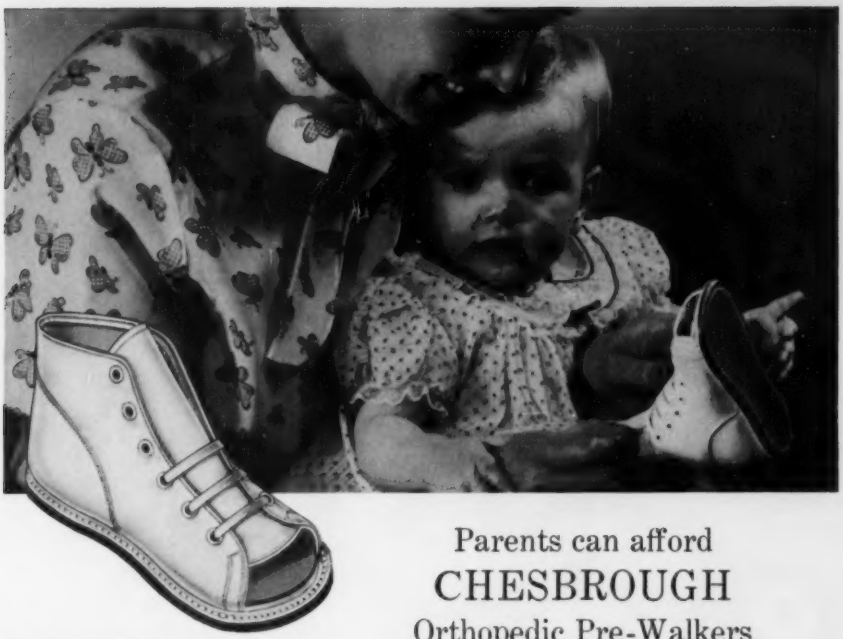
ERIE • PENNSYLVANIA



Parents can afford
CHESBROUGH
Orthopedic Pre-Walkers

No. 1400 OPEN TOE
Straight-line symmetrical last, firm heel, no back seam. Adaptable to Denis Browne Splints.

No. 1300 CLOSED TOE
Lace-to-toe design permits snug, gentle fit. Perfectly smooth inside.

No. 1700 CLUBFOOT, OPEN TOE
Special outflare last, sturdy instep strap to stabilize heel.

Louis C. Weld, President of G. W. Chesbrough Co. . . . "My own personal experience led to the development of the new Chesbrough Shoe."

Here are Orthopedic infants' shoes that meet rigid requirements of corrective footwear yet fit the family budget.

High-quality workmanship and fine leathers with orthopedically correct lasts are combined in Chesbrough Shoes to sell at a moderate price.

Any parent whose child requires orthopedic correction knows the expense is great, as frequent purchase of new shoes is required.

This problem was brought home to Chesbrough's president, Louis C. Weld, three years ago, when a child in his own family needed such a shoe. Recognizing the need for orthopedic shoes at an economical price, Chesbrough Company put their 60 years of shoemaking experience to work and Chesbrough Corrective Pre-Walker Shoes were born.

All shoes in unlined white elk, sizes 000 to 4, narrow and wide. Available in full pairs, split pairs or single shoes (no extra charge for half pairs).

MAIL COUPON FOR FREE DESK SAMPLES

G. W. CHESBROUGH CO.
807 Smith Street, Rochester 6, N. Y.

NAME .....

ADDRESS .....

CITY ..... STATE .....

YOUR ORTHOPEDIC SHOE DEALER:

.....

against pain

Zactirin®

Provides potent analgesic
and anti-inflammatory benefits
without sedation,
risk of addiction,
tolerance or constipation.

Supplied: Tablets, bottles of 48.

Wyeth Laboratories Philadelphia 1, Pa.

100 Anniversary Wyeth

A Century of Service to Medicine

Spencer

INDIVIDUALLY DESIGNED SUPPORTS

Supplement Vocational Rehabilitation

• Patient with extremely short stature and apron abdomen was unable to continue domestic employment following excision of large, pendulous breast. *(photo at left)*

• Through Vocational Rehabilitation Service, Spencer provided total body support to stabilize torso and anchor individually designed mastectomy brassiere. *(photo at right)*
Patient now continues employment and financial independence.

• Spencer controlled figure with patented, adjustable Previews to take measurements required to design patient's corset and brassiere to meet her individual requirements. *(center photo)*

Spencer's Individual Designing Service is available to you through Corsetieres specially trained to help you help your patients.

SPENCER®
individually designed supports for women, men and children

SPENCER, INCORPORATED
19 Ellsworth Ave., New Haven 7, Conn.
Canada: Spencer, Ltd., Rock Island, Quebec
England: Spencer, Ltd., Banbury, Oxon

☐ Send me the name of the nearest Spencer Corsetiere.

☐ I would like an office demonstration of Spencer benefits and features.

Name _____

Address _____

_____

3-60

De Puy

Lorenzo Screws

DePuy pioneered the development of the Lorenzo Screw and has, through years of experience, attained an unusually high degree of quality in their manufacture. Lorenzo Screws are furnished with either full thread or half thread. Made of SMo Stainless Steel. Available in the following lengths: 3", 3¼", 3½", 3¾", 4", 4¼", 4½", 4¾", 5", 5¼", 5½", 5¾", and 6".

No. 258SF (Full Thread) **No. 258SH (Half Thread)**

Lorenzo Bone Set for Hip Fractures

Assembled for the convenience of orthopedic surgeons, this set consists of 5 Lorenzo Screws (⅜" diameter), 1 Reamer, 1 Wrench, 1 Screw Rack, 2 Wires for fixation of the head of the femur (spear pointed).

No. 258 Set, complete

DePuy Universal Bone Plate

The DePuy Universal Bone Plate provides both vertical and lateral angulation to meet a wide variety of anatomical conditions. Can be regulated quickly and easily during surgery. Bending of plate not required. SMo Stainless Steel.

No. 693 (Lorenzo Screw not included)

Intertrochanteric Bone Plate, Double-Lock

The DePuy Intertrochanteric Bone Plate with Double-Locking Screw Combination can be used with Lorenzo Screw for maximum rigidity of fixation. Any friction tending to loosen screw will tighten it further. SMo Stainless Steel.

No. 318N (Lorenzo Screw not included)

Subtrochanteric Plate with Lock

A long popular plate for use with Lorenzo Screw in treatment of intertrochanteric fractures. The complete unit, made of SMo Stainless Steel, consists of Lorenzo Screw, Subtrochanteric Plate, Lock and Lock Screws. Plates are made in 4½", 5½", and 6½" lengths.

No. 333A Set (complete) **No. 333B Set (less Lorenzo Screw)**

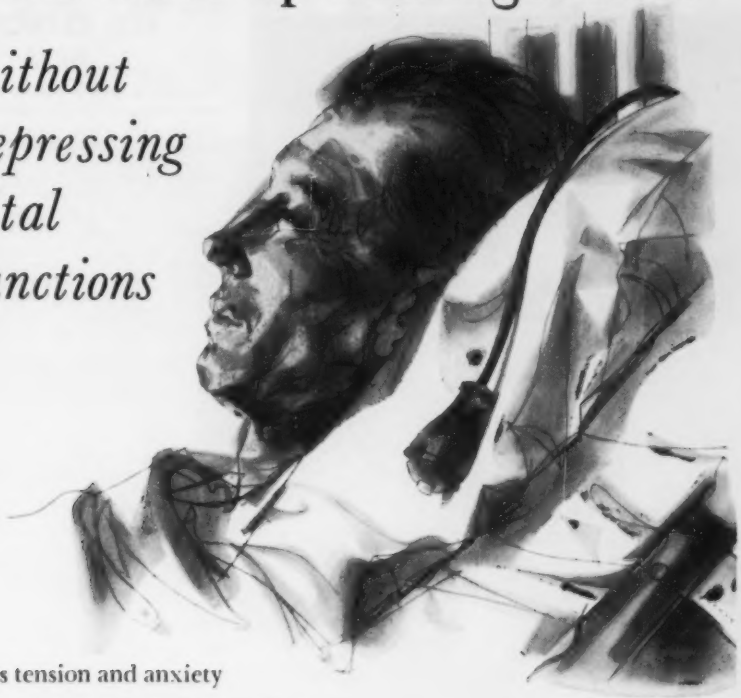
DePuy Manufacturing Co., Inc.

WARSAW, INDIANA

Since 1895—The Standard of Quality

Relieves Pre-op Apprehension Aids Post-op Management

without depressing vital functions



- relieves tension and anxiety
- helps provide "a good night's sleep"
- facilitates early ambulation
- relaxes skeletal muscle

Miltown has no adverse effects on cardiovascular, respiratory or gastrointestinal functions and causes no depressive "hang-over"

Miltown®
meprobamate (Wallace)

Miltown is available in 400 mg. scored and 200 mg. sugar-coated tablets; bottles of 50.

WALLACE LABORATORIES
New Brunswick, N. J.

Reprints available on request:

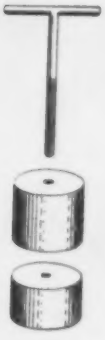
1. Kern, E. C.: Preoperative sedation with meprobamate (Miltown) in surgery of eye, ear, nose and throat. Eye, Ear, Nose & Throat Month. 36:408, July 1957.
2. Lamphier, T. A.: The value of meprobamate preoperatively. Maryland M.J. 7:627, Nov. 1958.
3. Lamphier, T. A.: Meprobamate —an important adjunct to post-operative surgical care. J. Maine M.A. 48:357, Oct. 1957.
4. Lamphier, T. A.: The role of meprobamate in postoperative surgical care. Ann. New York Acad. Sc. 67:810, May 9, 1957.
5. Rushia, E. L.: Preliminary report on the use of meprobamate for pre-anesthetic sedation. J.M.A. Georgia 46:93, March 1957.
6. Sadove, M. S. and Schiffrin, M. J.: Tranquilizers in surgery, in Surg. Clin. North America, Saunders, Philadelphia, Feb. 1959, pp. 231-244.

BOWEN FRACTURE APPLIANCES— GREAT AIDS TO BETTER SURGERY

LEG EXERCISER SETS

Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

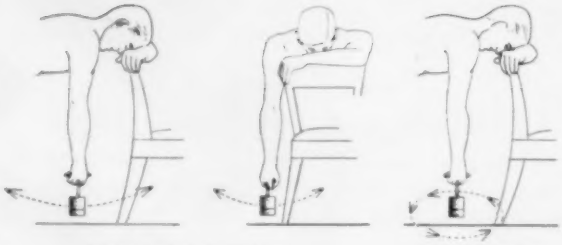
- **Rigid Construction—Relatively Light in Weight**
- **Moves Freely on Ball Bearings in All Directions**
- **Protractor Adjustment for Foot Angle Control**
- **Weight Attaching Eyes at Different Levels**
- **Foot and Heel of Exerciser Covered with Foam Rubber**
- **Exercising Board 14" x 48", Hinged at Center and Angled to Approximate the Arc Scribed by the Legs**



ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

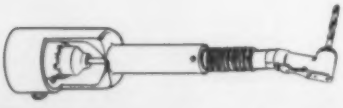
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



ANGLE DRILL ATTACHMENT

For Luck Bone Saw and Stryker Drill

Designed Especially for the Bankhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly constructed, light in weight. Entire unit may be sterilized. Two 3/32 inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

A hole in the end of the drill bit is provided so that the suture can be threaded and pulled through with the extraction of the drill.

GONIOMETER— Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

Produced from aluminum, anodized and dyed black, with white-lead-filled dial and indications permitting full penetration of radiation and screening a permanent secondary shadow of measurement on the film for consultations and computations.

BOWEN & COMPANY

INC.

P. O. Box 5818

BETHESDA, MARYLAND

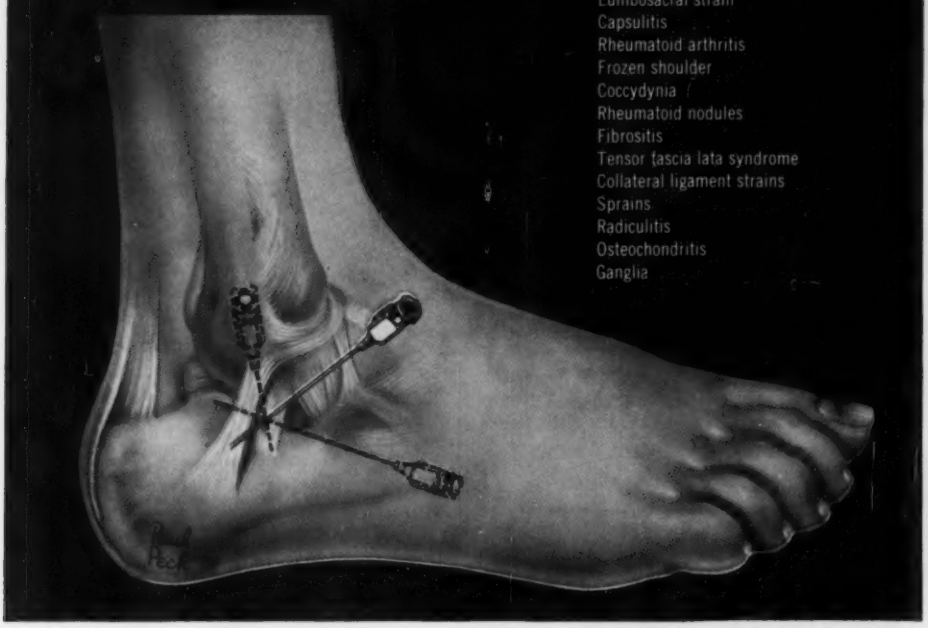
HYDELTRA® -T.B.A.

(Prednisolone tertiary-butylacetate, Merck)

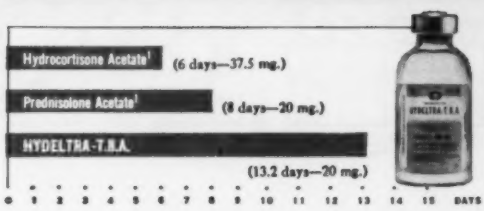
for relief that lasts—longer

in *SPRAINS*—
reduces tenderness,
swelling and
limitation of motion

Osteoarthritis
Acute gouty arthritis
Bursitis
Tendinitis
Trigger finger
Peritendinitis
Trigger points
Tennis elbow
Lumbosacral strain
Capsulitis
Rheumatoid arthritis
Frozen shoulder
Coccydynia
Rheumatoid nodules
Fibrositis
Tensor fascia lata syndrome
Collateral ligament strains
Sprains
Radiculitis
Osteochondritis
Ganglia



Anti-inflammatory effect lasts longer than that provided by any other steroid ester


Hydrocortisone Acetate[1]
(6 days—37.5 mg.)
Prednisolone Acetate[1]
(8 days—20 mg.)
HYDELTRA-T.B.A.
(13.2 days—20 mg.)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 DAYS

Dosage: the usual intra-articular, intra-bursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

Supplied: Suspension 'HYDELTRA'-T.B.A.—20 mg./cc. of prednisolone *tertiary*-butylacetate, in 5-cc. vials.

MSD

MERCK SHARP & DOHME
DIVISION OF MERCK & CO., INC.
PHILADELPHIA 1, PA.

"It is actually difficult to find the threads in a Gypsona Plaster Bandage"

A deeply-buried fabric that molds firmly around protuberances and *indentations,* a plaster that feels almost like pure cream in your hands, a cast with the glint of polished marble—these and other refinements continue to set Gypsona* apart

CONSIDER why this particular plaster bandage is the more prominent in a majority of the world's hospitals. Why is it the choice of so many noted orthopedic surgeons.

The reason is one of classic simplicity. Gypsona technique goes beyond "selling features", such as strength, price and the like.

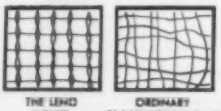
A Matter of Total Quality

This is one of those all too few cases where a manufacturer is intent on total quality. Where he concentrates not on a competitive plus, but on every characteristic vital to casts and their effective fracture treatment.

A Different Twist

The leno fabric, for instance. It was developed for a number of reasons. For conformability. To prevent the sliding of threads. To hold more plaster. To eliminate the sawtooth edge.

Instead of a simple crosshatch weave, two (rather than one) longitudinal threads are twisted—locking in the horizontal thread. Giving you an extraordinary conformability. You can mold a Gypsona Plaster Bandage around bones, protuberances—even identations! A rare advantage, indeed, in the treatment of fractures.



The Plaster is Sewn In

With this leno weave, every thread is anchored. All but eliminates the nuisance of "sliding threads". A high plaster content is retained. Sewn in, so to speak.

As one eminent orthopedic surgeon remarked, "Unlike other bandages, it is actually difficult to find the threads in Gypsona."

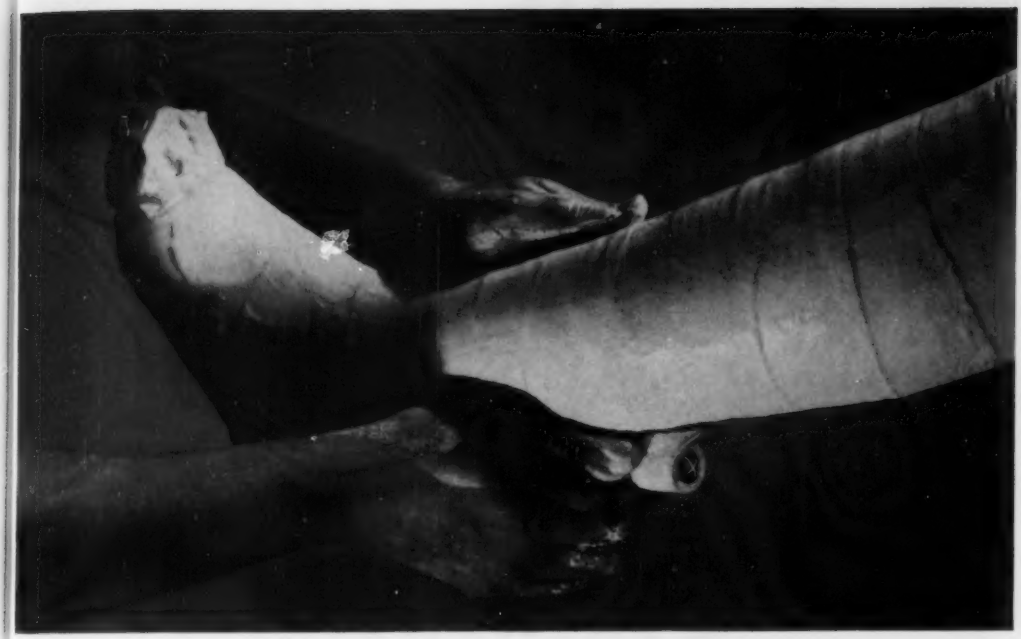
"The Cream of Plaster Bandages"

Quarried and processed in England, Gypsona plaster is of a finely-ground texture. Only your hands can appreciate fully the soft compatibility of such a gritless plaster. You dip and then you *squeeze the wet bandage gently, tenderly.* Leave the hard wringing to the more coarse plasters. "It's the cream of the plaster bandage crop" is how a surgeon in South Africa put it.

Reduces Temptation

Four to five minutes is the routine setting time. (For many, this short, precise setting represents a sort of challenge.) You don't have to hold the liml . s long. And, incidentally, such celerity reduces the temptation to add "one more bandage".

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*



Light, Strong and Mobile

The upshot is a light cast. Light, strong and mobile. Patients are inclined to use the limb a little more freely. You can look for a somewhat faster rehabilitation when you use Gypsona.

A Marble-like Luster

Worth noting, too, is the fact that the cast never comes out looking like divinity fudge. The finished cast has a marble-smooth cleanness. Patients can feel reasonably neat in appearance. Ordinary soiling is easily wiped or washed away.

Plastic Core and Airtight Package

Not to be overlooked is the ease of unwinding with the Gypsona plastic core. Prevents "telescoping". And then there's the airtight package. Plaster stays fresh almost indefinitely. You have no pre-setting problem.

A Broad Versatility

As you would expect, a Gypsona bandage costs more. Only a few cents per cast, however. In return, you receive a bandage that performs *all* the functions unusually well. And, with uncommonly broad versatility.

Interested? Get in touch with your Bauer & Black representative. He's the man who brings the Gypsona Plaster Bandages to America.

FREE BOOK

"Gypsona Technique", textbook of modern plaster methods, 140 illustrations. Write Bauer & Black, 309 W. Jackson Blvd., Chicago 6, Ill.

Curity®/Gypsona* **PLASTER BANDAGES**

THE KENDALL COMPANY
BAUER & BLACK
DIVISION

*Reg. T. M. of T. J. Smith and Nephew Ltd.

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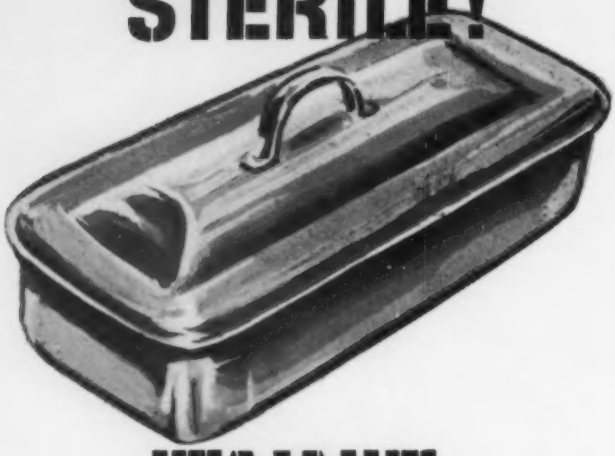
'TiS STERiLE!



'TAiN'T STERiLE!

The nice old lady who scored her pie crusts "TM" and "TM" ('Tis or 'Tain't Mince) never knew which was which. So it is with "homemade" petrolatum gauze...there's always the question of sterility. That's why most hospitals specify 'Vaseline' Sterile Petrolatum Gauze U.S.P. This label insures the absolute sterility that is difficult to attain in hospital-made gauze.

Available in 6 sizes

IN DISPOSABLE PLASTIC TUBES

½" x 72" selvage-edged strips, 6 to box

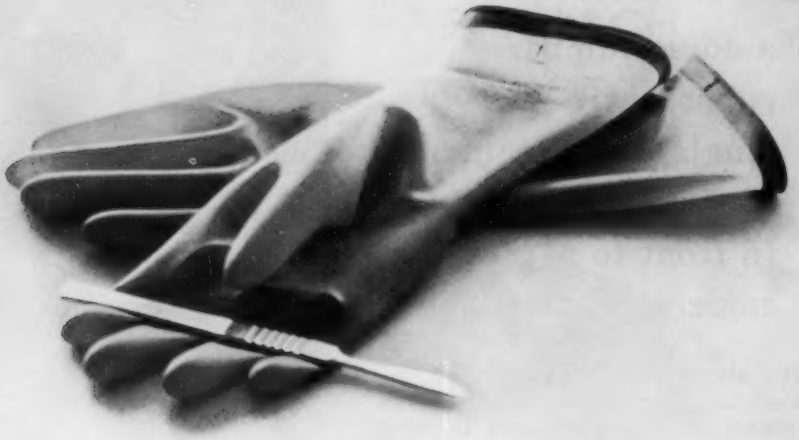
IN HEAT-SEALED FOIL ENVELOPES

3" x 3" pads, open to 3" x 9" strips, 6 to box
1" x 36" strips, 6 to box
3" x 18" strips, 6 to box
3" x 36" strips, 6 to box
6" x 36" strips, 6 to box

PROFESSIONAL PRODUCTS DIVISION
Chesebrough-Pond's Inc., New York 17, N. Y.

VASELINE® STERILE PETROLATUM GAUZE

'TiS STERiLE!



helps smooth the surgical course for both patient and O-R team

Reports on the value of PHENERGAN in surgery are many, and they continue to grow in number. Typical of the conclusions drawn are those of Adelman[1] and his co-workers, who recently reported on 4300 patients undergoing surgery at Mt. Sinai Hospital, New York City.

As preanesthetic medication, PHENERGAN in combination with scopolamine and reduced doses of meperidine "afforded optimal sedation without significant respiratory or circulatory depression."

Induction and maintenance of general anesthesia were "facilitated . . . [PHENERGAN] appeared to reduce requirements of general anesthetic agents."

Nausea and vomiting were "practically eliminated . . . in the preoperative and operative periods . . . the incidence of postoperative nausea and emesis after general anesthesia was markedly reduced."

allays apprehension • facilitates anesthesia • prevents nausea and vomiting

1. Adelman, M.N., et al.: J.A.M.A. *169*:5 (Jan. 3) 1959.

PHENERGAN®
HYDROCHLORIDE
Promethazine Hydrochloride, Wyeth
Injection • Tablets • Syrup • Suppositories

Wyeth®
Philadelphia 1, Pa.

For the first time...

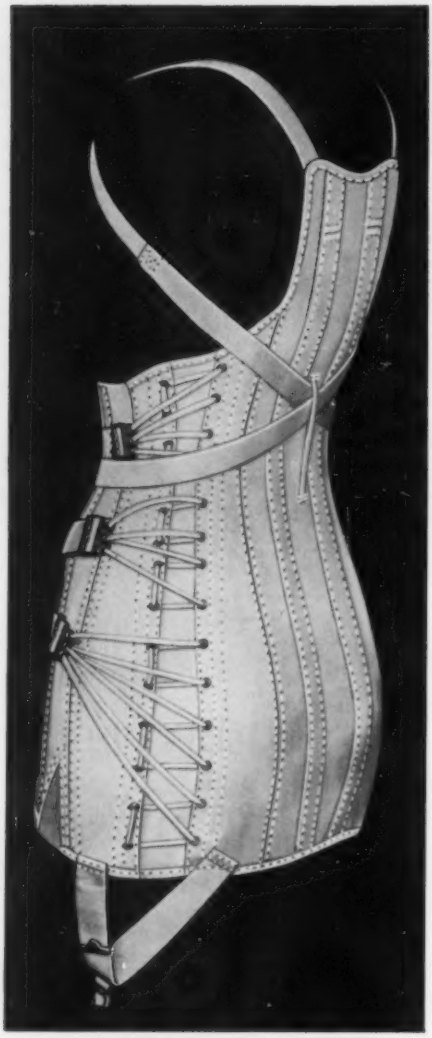
a dorso-lumbar support with single adjustment of shoulder straps in front to assure correct support

It's always been a problem for the patient to adjust satisfactorily the conventional dorso-lumbar support. In order to adjust shoulder straps at each side, the patient has to turn the shoulders out of normal position. This makes it difficult to attain the optimum support for the upper back.

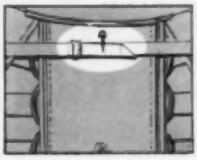
Now Truform has the answer . . . shoulder straps that are tightened by a single adjustment in front, as shown in the drawing. No twisting and turning to each side. The patient's shoulders stay in their normal position, the adjustment firmly maintains the desired corrective position. The tightened straps, which cross in the back, are then held securely in a simply designed "keeper" (shown in drawing).

Greater height in the back, too, with two full-height steel stays to assure firm support. Comfortable adjustable underarm pads . . . 3 pull-straps to adjust and distribute tension.

Always look to Truform supports that are anatomically correct and therapeutically sound . . . fitted with skillful knowledge . . . available to you and your patients only from the Ethical Appliance Dealer.



NEW DORSO-LUMBAR SUPPORT



Women's models 1173-HS full skirt (pictured above) and 1174-HS regular length. Men's model 417-HS regular length. Drawing shows single adjustment of shoulder straps in front, retained in "keeper".

TRUFORM

anatomical supports

3960 Rosslyn Drive, Cincinnati 9, Ohio

Branches: New York and San Francisco

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

A NEW APPROACH TO FOOT PROBLEMS

Style No. 84

Alden-Pedic SCIENTIFIC CONSTRUCTION SHOES

Preferred by the Nation's Leading Foot-Fitting Specialists

- Long inside counter
- Right and left ortho heels, long inside
- Heavy gauge right and left ribbed steel shank.
- New "Depth Design" accommodates prescribed corrections

WRITE FOR BOOKLET AND NAME OF NEAREST DEALER

Alden-Pedic lasts and shoes serve 3 purposes:

- **Fit the individual foot shape . . .**
- **Accommodate your prescribed corrections . . .**
- **Provide a stable, controlled foundation.**

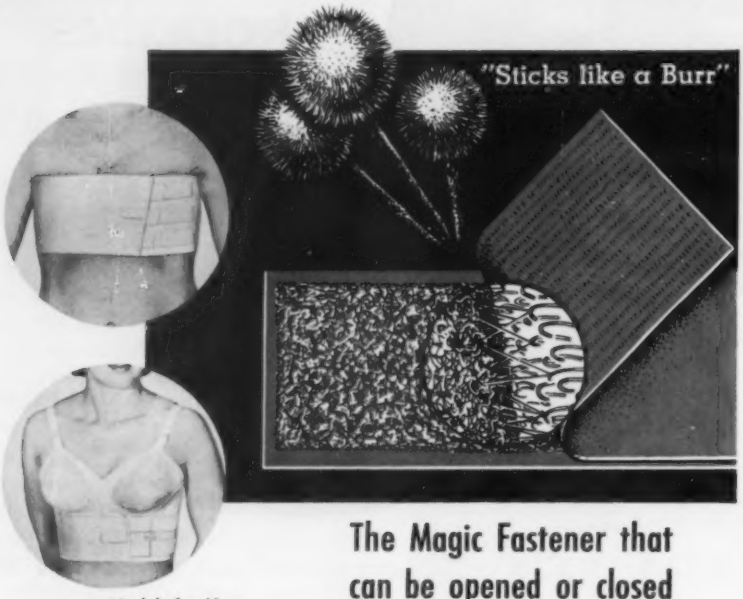
Write us today for our new illustrated brochure of Alden-Pedic styles for men and boys and our new "Progress Report on Shoe and Last Design."

C.H. ALDEN SHOE COMPANY

Custom Bootmakers Since 1884

BROCKTON, MASSACHUSETTS

NEW from Orthopedic
RIB SPLINTS made with VELCRO®



Models for Men and Women

The Magic Fastener that can be opened or closed thousands of times!

Now . . . all elastic rib splints by Orthopedic feature this new concept in fastening . . . VELCRO . . . the nylon tape that grips instantly, removes easily, and adjusts readily. Eliminates old fashioned belts and buckles.

You'll find it profitable to stock and sell this newest FIRST by Orthopedic. Rib splints with VELCRO are offered in both male (No. 768); and female (No. 868) models; and in **four** sizes: small (24 to 30); medium (30 to 36); large (36 to 42); and extra large (42 to 48). List Price $39.00 per Doz.

Order your supply today!

OEC

Plants also in Great Britain and Germany

Orthopedic EQUIPMENT CO.
BOURBON · INDIANA

SPLINTS · FRACTURE EQUIPMENT · BONE INSTRUMENTS
SMO INTERNAL BONE APPLIANCES · ORTHOPEDIC SUPPLIES

specific treatment for arthritic joints

intra-articular/intrasynovial/intrabursal instillation

□ **good to excellent response in a vast majority of patients**—"Low doses...provided rapid and effective relief...in almost all of the 157 patients treated..."[1] "...appeared to be superior as an intra-articular injectable substance to anything hitherto available."[2]

□ **provides sustained, long lasting benefits**—In 28 out of 34 patients,"...complete relief was provided by a single injection...the relief lasting for an average of more than 2.5 months."[2]

□ **rapid relief of pain, swelling, and improved range of motion**—"Pain was relieved in 3 or 4 days, or less..."[3] "...marked improvement in range of motion occurred in all of these patients."[3] "...more potent, milligram for milligram, than other injectable corticosteroids."[4]

□ **undesirable side reactions outstandingly rare**—"...appears to be a safe, potent, and effective preparation..."[5] "...tolerated as well as or better than hydrocortisone or prednisolone."[6]

Dosage: usual doses—2.5 to 5.0 mg. for smaller joints; 5.0 to 15.0 mg. for larger joints. *Side Effects:* outstandingly rare; although systemic effects do not ordinarily occur with Kenalog Parenteral when the proper techniques and dosages are used, careful clinical supervision is advisable for all patients receiving steroid therapy. *Contraindications:* infections in or near joints—e.g., gonococcal or tuberculous arthritis. *Supply:* a sterile aqueous suspension in 5 cc. vials, each cc. providing 10 mg. triamcinolone acetonide. *References:* 1. Sperling, I. L.: Clinical Research Notes vol. 3, No. 1 (Jan.) 1960. 2. Steinberg, C. L.: op. cit. 3. Urist, M. R.: op. cit. 4. Meltzer, L. E.: op. cit. 5. Schwartz, S.: op. cit. 6. Felts, W. R.: op. cit.

Among 363 patients treated with Kenalog Parenteral, 315 (86.7%) obtained complete relief or were markedly improved.[1-6]

new **Kenalog Parenteral**

Squibb Triamcinolone Acetonide Aqueous Suspension

SQUIBB

Squibb Quality—the Priceless Ingredient

'KENALOG'® IS A SQUIBB TRADEMARK.

CAMP TRADE MARK *dorsolumbar supports*

For Conservative Treatment of Orthopedic Conditions

This groin length support features Camp's famous double side-lacing adjustment. Note how the back cups well under the gluteus and extends over the scapula to assure rigid support with least discomfort. Casings in back permit extra steels for added reinforcement.

Made of strong cream fabric, this support comes equipped with two 17" shaped steels. The triple side-lacing adjustment, elastic releases at top front and groin, and the foam rubber padded shoulder straps provide both comfort and strong support.

Some of the many conditions in which it is necessary to support a portion or all of the dorsal vertebrae include: dorsal spine fractures, operative procedures, arthritis, juvenile osteochondritis and cases of strain in the more severe forms of faulty body mechanics. Camp designs the most complete line of supports for such cases (4 women's supports, 3 men's supports and children's supports) to meet the specific requirements of the physician and the cosmetic needs of the patient.

All models feature the side-lacing adjustments to help steady the pelvis and provide accompanying support to the gluteal region. Padded shoulder straps and a well boned back gives even more rigid-support when reinforced with strong pliable steels to the lumbar area and parts of the dorsal spine.

Detailed information available on request

S. H. CAMP & COMPANY, JACKSON, MICHIGAN

CAMP TRADE MARK

S. H. Camp & Company of Canada, Ltd., Trenton, Ontario

Reprints suitable for framing available upon request

Stryker

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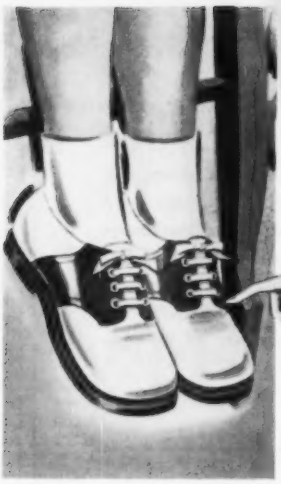

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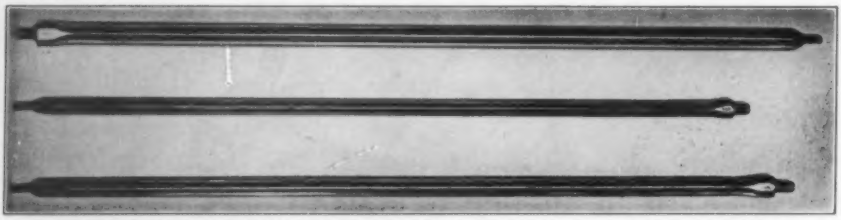

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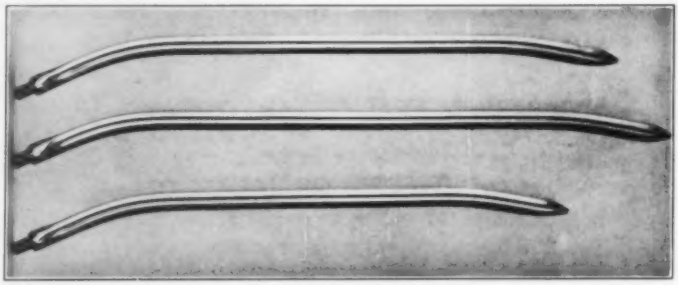

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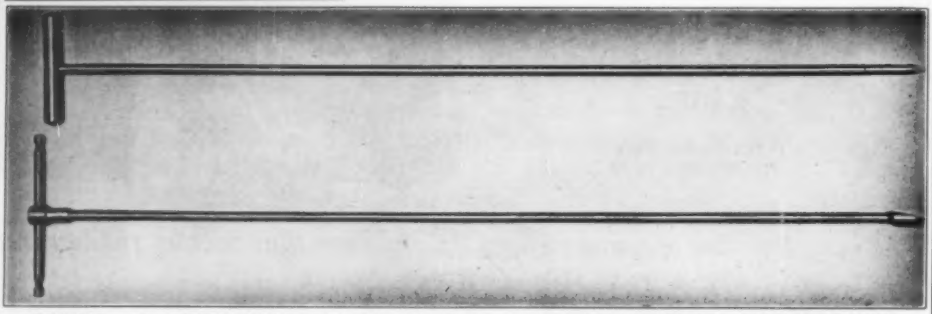

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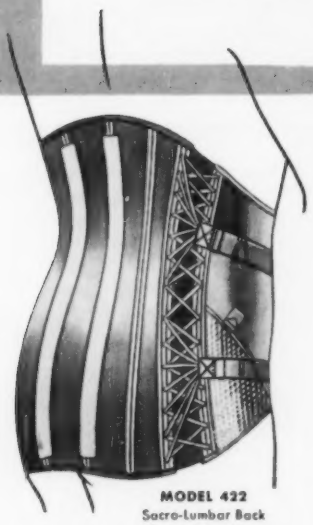

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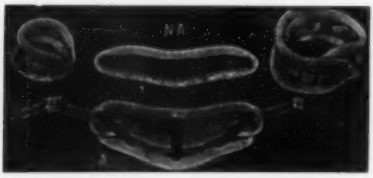

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VOLUME 42-A, NO. 2 MARCH 1960

The Journal of
Bone and Joint Surgery
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Correlation of the Myelogram with Clinical and Operative Findings in Lumbar Disc Lesions*

BY W. EDWARD LANSCHE, M.D.**, AND LEE T. FORD, M.D., ST. LOUIS, MISSOURI

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The syndrome of low-back pain with or without sciatica is one of the more common diagnostic problems that the orthopaedist faces in his daily practice. Since 1934 when Mixter and Barr described the syndrome of the ruptured intervertebral disc and showed that the condition could, if necessary, be treated by operation, the surgeon has searched for accurate methods of definite diagnosis prior to surgery. Following the concepts of Walter Dandy it was the practice on the Orthopaedic Surgery Service at Barnes Hospital prior to 1946 not to employ the myelogram in those patients operated on for disc lesions in the lumbosacral spine, since it was believed that an accurate diagnosis and localization of the lesion could be made by history and physical examination. However, in September 1946, myelograms were employed in a series of patients with low-back pain in the hope that this would improve the results in their diagnosis and treatment. In 1949 Ford and Key reported to The American Orthopaedic Association their experience with myelography in 253 patients, of whom 206 had surgical exploration of the lumbosacral canal. They found a positive correlation in 72.3 per cent and felt that the myelogram was a valuable aid in diagnosis and may be a decisive factor in borderline cases. At that time they felt that not every patient having signs and symptoms referable to a lumbar disc should be subjected to a lumbar myelogram but that it should be reserved for those patients in whom the diagnosis or the location of the lesion was not sufficiently clear to enable the surgeon to operate with confidence.

In 1952 Ford, Ramsey, Holt, and Key reported their additional experience with 100 consecutive patients who had myelography followed by surgical exploration of the lumbosacral canal for a ruptured intervertebral disc. A 60-per cent positive correlation was found, and again it was felt not necessary to subject every patient with a suspected disc lesion to myelography if the history, clinical course, and physical findings definitely indicated a disc lesion and the surgeon was able to determine its approximate location.

Since that time the myelogram has been used more extensively, and in the past seven years almost every patient on the Orthopaedic Surgery Service suspected of having a lumbar intervertebral disc lesion requiring surgical interven-

* Read at the Annual Meeting of The American Orthopaedic Association, Lake Placid, New York, June 18, 1959.

** J. Albert Key Memorial Fellow in Orthopaedic Surgery.

tion has had a myelogram. We have tried to summarize our entire experience with lumbar myelography and to correlate this with the clinical and operative findings.

METHOD OF STUDY

Included in this study are the two previously reported series and 560 additional cases on the private and ward teaching orthopaedic surgery services at Barnes Hospital and private orthopaedic patients at the Missouri Baptist Hospi-

FIG. 1

The patient was a white woman, forty-one years old, who noted the onset of low-back pain and sciatica on the left side after childbirth fifteen months previously. The symptoms gradually increased in severity. Physical examination showed a list to the left side, a flattened lumbar curve with limited and painful motion of the lumbar spine, a positive straight-leg-raising test on the left side, three centimeters of atrophy of the left calf, a weak extensor hallucis longus of the left leg, and no sensory or reflex change.

The myelogram showed a large indentation type of defect at the level of the fourth lumbar vertebra on the left side. At surgery a protruded disc was removed. The myelographic and surgical findings were in accord.

tal. This group of 866 patients does not constitute a consecutive series nor does it represent the entire number of myelograms done on the orthopaedic services during the time interval from 1946 to 1959. Because of deficiencies in our record system, cases which should have been included in this series have probably been overlooked. It is not, on the other hand, a selected group of cases.

Only the series of 100 patients and the present group of 560 patients are analyzed in detail. The observations made by various members of the visiting and resident house staffs were abstracted from the hospital records and analyzed. The statistical analyses of these observations are, of course, subject to error since, undoubtedly, these observations would have been different if all the patients had been examined and operated on by one or two trained observers. All myelograms were reviewed by one of us, and in cases of discrepancy the myelographic findings were reviewed by both of us and the operative findings again checked before the discrepancy was counted as such.

FIG. 2

The patient was a white man, forty-eight years old, with a four-year history of severe low-back pain and sciatica on the right side after an automobile accident. He had a flattened lumbar curve with a list to the left, a positive straight-leg-raising test on the right side, a weak extensor hallucis longus, and no sensory or reflex change.

The myelogram showed an hourglass defect at the level of the fourth lumbar vertebra. At surgery a protruded mid-line disc was removed from the level of the fourth lumbar intervertebral space. The myelographic and surgical findings were in accord.

TECHNIQUE OF MYELOGRAPHY

The patient is usually given preliminary medication of a mild opiate and a barbiturate about thirty to sixty minutes before the procedure, to help allay apprehension and to facilitate the dye removal which may be painful because of the needle pressing on or sucking against a nerve root.

The skin is prepared with the antiseptic of choice. A skin wheal is raised with 1 per cent novocain at the third lumbar intervertebral space, and the area infiltrated. With the patient either lying on his side or in a sitting position, the lumbar puncture with a No. 18 needle is performed, with an attempt made to insert the needle exactly in the mid-line. If the lumbar puncture is done when the patient is sitting, the patient is eased onto his side, and five to ten cubic centimeters

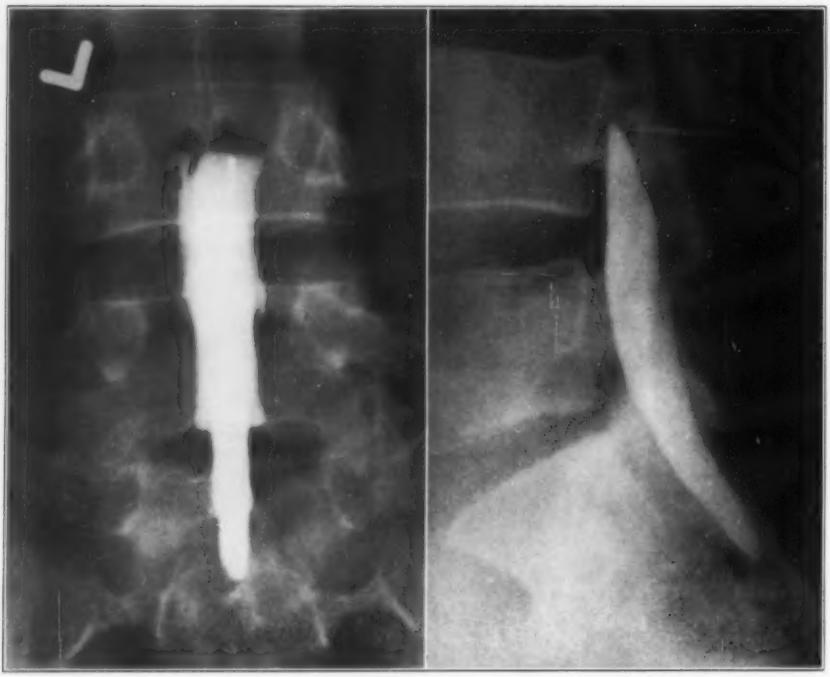

FIG. 3

The patient was a white man, thirty-three years old, with a four-year history of low-back pain and sciatica on the left; the onset of pain was acute while the patient was lifting an object. The physical examination revealed tenderness over the fifth lumbar vertebra, limited lumbar-spine motion, hypesthesia over the fifth lumbar dermatome on the left, and no reflex change or motor weakness.

The myelogram showed a defect of the nerve-root sleeve on the left side at the fourth vertebral interspace in the anteroposterior view. The lateral view showed only edematous nerve roots. At surgery a protruded lumbar disc was removed from the left side of the fourth vertebral interspace. The myelographic and surgical findings were in accord.

of spinal fluid is removed for cell count, protein determination, and other laboratory tests, as indicated. Five to six cubic centimeters of pantopaque, which has previously been warmed to body temperature, is withdrawn slowly and evenly from the ampules and is injected in the same manner into the subarachnoid space.

The stylet is then inserted in the needle, and the needle is covered with a sterile towel which is held in place with tape. The patient is laid prone on a tilt-top fluoroscopic x-ray table, and the movement of the pantopaque column is watched closely on the fluoroscopic screen as it flows up and down in the dural sac as the position of the patient is changed from an erect to a prone position. The head of the dye column is watched carefully at each disc level as it begins to flow over the disc, because it may then reveal a small defect which is hidden when the full dye column flows over the disc. Large defects can often be seen at a glance, but small ones may be hard to identify. Spot roentgenograms to include anteroposterior, right and left posterior-oblique views, and a prone lateral view are obtained of the lumbosacral, the fourth and the third lumbar disc spaces, and other levels where indicated.

After fluoroscopic and roentgenographic studies have been completed, the dye is pooled around the tip of the needle under fluoroscopic control, and as much pantopaque as possible is removed. At times it may be necessary to do a second lumbar puncture at a lower level to facilitate removal of the dye. This is especially true if the original lumbar puncture has been made at a level higher than the

FIG. 4

The patient was a white man, forty-three years old, who had had low-back pain for three months and sciatica on the left for one month; the onset of pain was acute while the patient was lifting an object. He had painful, limited motion of the lumbar spine, with flattening of the lumbar curve, and tenderness over the lumbosacral junction. Bilaterally, the straight-leg-raising test was markedly positive and the ankle jerks were absent; the extensor hallucis longus of the left leg was weak. There was no sensory change.

The myelogram showed a complete block at the lumbosacral intervertebral space. At surgery a large fragment of disc material was found to have extruded into the subarachnoid space, and transdural removal was necessary. The myelographic and surgical findings were in accord.

third lumbar intervertebral space. It is usually possible to remove most but not all of the radiopaque medium.

INTERPRETATION OF THE MYELOGRAM

In studying the spot roentgenograms made at myelography, a search is made for defects of the following types:

1. A lateral indentation of the dye column noted on the anteroposterior view, which is illustrated in Figure 1, is the most common type of defect and is the one usually associated with a ruptured disc. This occurred in 62.9 per cent of the defects we noted on myelography. The indentation may be large or small and indicates a lateral protrusion of the disc. The size of the indentation is not necessarily a reliable indication of the size of the rupture of the disc.

2. An hourglass deformity (Fig. 2) produced by a mid-line herniation of the disc occurred in 16.4 per cent of the defects noted at myelography. Begg, Falconer,

and McGeorge attributed this type of defect to the mid-line rupture of the disc crowding the intradural nerve roots at that level to each side, leaving a thin, narrow channel in the mid-line over the dome of the protrusion; as the patient is tilted the medium flows up or down this channel.

3. Asymmetry, elevation, or non-filling of the nerve-root sleeve on one side occurs more commonly at the lumbosacral level and may be indicative of herniation of the disc. Nerve-root-sleeve defects (Fig. 3) occurred in 14.9 per cent of the defects. This type of defect is more subtle and is often overlooked and should be searched for since it may be considered normal by some observers.

4. Block-type defects occurred in 5.8 per cent of the defects. The block may be complete or incomplete and usually has a shaggy outline which most often is located over the disc space but which may also be located over the body of the vertebra. Occasionally, the block defect may have a smooth outline, and, if lo-

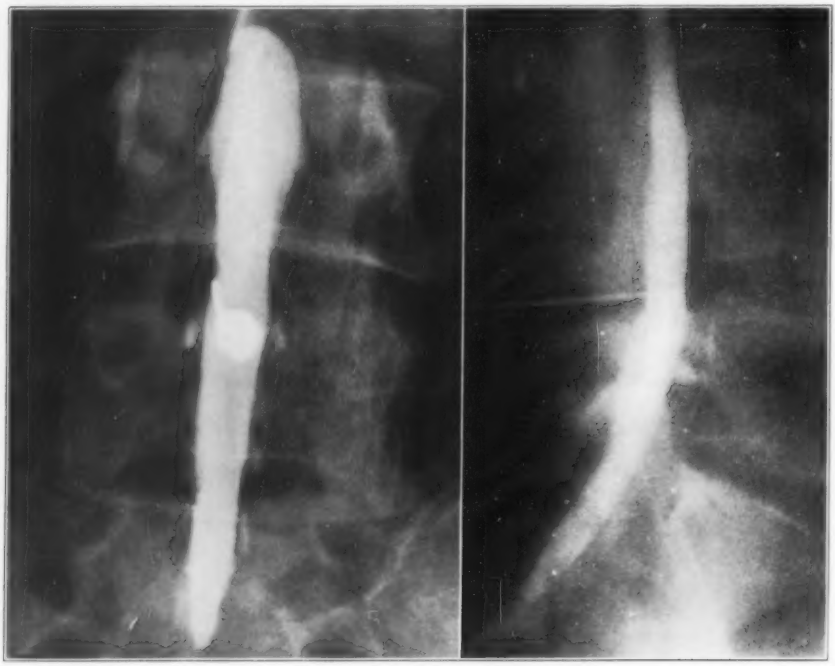

FIG. 5

The patient was a white man, twenty-eight years old, who had had low-back pain and sciatica on the left side for one year; the onset was acute after an injury. There were a list to the left, tenderness over the fourth and fifth lumbar intervertebral spaces and along the course of the left sciatic nerve, a positive straight-leg-raising test on the left side, hypalgesia over the left fifth lumbar dermatome, a weak extensor hallucis longus, and no reflex change.

The myelogram was negative. At surgery a protruded disc was removed from the left side at the fifth lumbar intervertebral space, and exploration of the fourth intervertebral space was negative. There was a major discrepancy between the myelographic and surgical findings.

cated at the lumbosacral interspace, may simulate a congenitally short dural sac. A roentgenogram of the patient in the prone lateral position is especially important in the block type of defect in differentiating rupture of the disc from intradural tumor.

Complete myelographic blocks may simulate a cauda equina tumor (Fig. 4). In three patients with such complete blocks on the myelograms, transdural removal of the disc was necessary because of intradural location of the extruded disc material. This type of disc herniation is uncommon but could easily be overlooked

TABLE I

LOCATION OF 704 RUPTURED DISCS REMOVED AT SURGERY IN 660 PATIENTS

Level of Disc	No. of Unilateral Discs	No. of Mid-Line Discs	Total
L 1	1	0	1
L 2	2	0	2
L 3	29	10	39
L 4	302	58	360
L 5	279	23	302
Totals	613	91	704

at the time of surgical exploration if a myelogram has not been done to locate the ruptured disc.

RESULTS

In 660 patients in the last two series there were 447 males (67.8 per cent), with an average age of 41.6 years, and 213 females (32.2 per cent), with an average age of 41.2 years. The youngest male was seventeen, and the oldest was seventy-six. The youngest female was eighteen, and the oldest was sixty-one. Of the patients, 86.7 per cent were private and 13.3 per cent were on the ward teaching service: 3.3 per cent of these patients had low-back pain only; 90.8 per cent had low-back pain with sciatica; and 5.9 per cent had sciatica only. In 57.5 per cent of the patients there was a history of injury of varying magnitude prior to the onset of symptoms, whereas 42.5 per cent of patients had onset of symptoms without a history of injury. An injury is taken to mean an unusual traumatic incident over and above everyday activity.

The preoperative localization of the disc lesion based on clinical interpretation was accurately correlated with the operative findings in only 39.2 per cent of the patients. This does not refer to the accuracy in making the clinical diagnosis of a ruptured disc but rather to the exact preoperative localization of the ruptured disc by means of the neurological examination.

The spinal-fluid protein was analyzed in those patients with myelographic defects which were proved at surgery to be caused by ruptured discs. The average spinal-fluid protein was 53.8 milligrams per 100 cubic centimeters, with a low of 17 and a high of 955 milligrams per 100 cubic centimeters. In the patients with negative surgical exploration for a ruptured disc, the average spinal-fluid protein was 45.6 milligrams per 100 cubic centimeters, with a low of 26 and a high of 86 milligrams per 100 cubic centimeters. In one patient with a neurilemoma arising from the root of the right fifth lumbar nerve and showing a complete block at the level of the fourth lumbar intervertebral space, the spinal-fluid protein was

TABLE II

COMPARISON OF MYELOGRAPHIC AND OPERATIVE FINDINGS IN THREE STUDIES

Study	No. of Myelograms with Surgery	No. of Positive Correlations	No. of Minor Discrepancies	No. of Major Discrepancies
Ford and Key, 1950	206	149 (72.3%)	17 (8.3%)	40 (19.4%)
Ford, Ramsey, Holt, and Key, 1952	100	60 (60%)	12 (12%)	28 (28%)
Lansche and Ford, 1959 (present study)	560	453 (80.9%)	25 (4.5%)	82 (14.6%)
Totals	866	662 (76.4%)	54 (6.2%)	150 (17.3%)

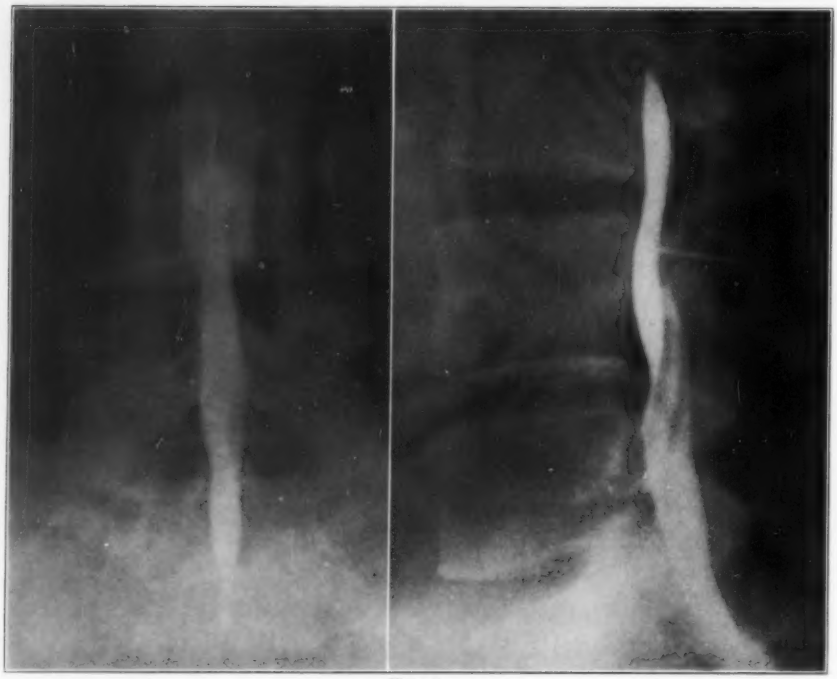

FIG. 6

The patient was a white man, thirty-nine years old, who had had low-back pain for five years and sciatica on the right side for four and one-half years after a twisting injury. There were moderate limitation of lumbar-spine motion, a positive straight-leg-raising test on the right side, a slightly decreased knee jerk and absent ankle jerk on the right side, hypesthesia over the fifth lumbar and first sacral dermatomes on the right, and no muscle weakness.

The myelogram showed a mid-line defect at the level of the fourth lumbar vertebra. At surgery an extruded disc was removed at the level of the fifth lumbar intervertebral space, and exploration of the fourth intervertebral space was negative. There was a major discrepancy between the myelographic and surgical findings.

214 milligrams per 100 cubic centimeters. In another patient with an ependymoma located at the level of the second lumbar vertebra, the spinal-fluid protein was 2,150 milligrams per 100 cubic centimeters.

In Table I are shown the distribution and location of the actual number of ruptured discs removed in 660 patients in the last two series. Reynolds, McGinnis, and Morgan pointed out that in women the fourth lumbar disc space was involved in the majority of their patients, whereas in men there was no predilection for any given level. Our findings indicate that herniation of the disc is a little more frequent at the fourth lumbar-vertebra level, and that mid-line herniations are twice as frequent at the fourth lumbar-vertebra level as at the lumbosacral level.

In this group of 704 discs removed from 660 patients, there were fifteen soft (2.1 per cent), 304 bulging (43.2 per cent), 178 protruded (25.3 per cent), 187 extruded (26.6 per cent), and twenty inspissated discs (2.8 per cent). The term extruded disc refers to one in which the nuclear cartilage lies free in the spinal canal, whereas a protruded disc is one in which the annulus fibrosus is no longer intact, but the nuclear cartilage is covered by the intact posterior longitudinal ligament. A bulging disc is one which bulges posteriorly for an abnormal amount and in which the annulus fibrosus, although degenerated and relaxed, is intact. A soft disc is one which has much less tension than normal, contains degenerated nuclear cartilage, and in which two cubic centimeters or more of saline or novocain

FIG. 7

The patient was a white man, thirty-eight years old, with a history of two previous operations for removal of a lumbar disc. After the second operation he continued to have low-back pain and sciatica on the right side which gradually worsened and became incapacitating. Physical examination showed a slight list to the left, limited lumbar-spine motion, tenderness over the lower lumbar spine, and a positive straight-leg-raising test and decreased knee and ankle jerks on the right side.

The myelogram showed a partial block at the level of the fourth lumbar vertebra. At surgery, only postoperative scar tissue was found at the level of the fourth and fifth lumbar vertebrae. There was a major discrepancy between the myelographic and surgical findings.

solution can be injected. An inspissated disc is one which has collapsed, with its residual disc space filled with scar tissue. The dura and nerve root may be adherent to the floor of the canal at the level of an inspissated disc.

In Table II is shown the diagnostic accuracy of myelography as shown by surgical exploration in the three series. The over-all accuracy of the three series comprising 866 patients is 76.4 per cent. In the last group there was some improvement compared with the first two series, but the procedure still is not completely accurate.

In 453 patients of the present series of 560 cases the operative findings were in complete accord with the myelographic findings, giving an accuracy of 80.9 per cent. In twenty-one of these patients the preoperative myelogram was negative, and at the time of surgical exploration no evidence of an intervertebral disc lesion was encountered.

In eighty-two patients (14.6 per cent) in this series there were major discrepancies between the myelographic and surgical findings. In twenty-eight patients (5 per cent) the myelograms were considered negative but abnormal discs were found at surgery (Fig. 5). In two of these patients two separate ruptured discs were present at the same time, but neither of the ruptured discs was indicated by myelography. In forty-four patients (7.9 per cent) abnormal discs were

found and removed at different levels or from the opposite side from the indications shown on the myelograms (Fig. 6). No adequate explanation can be given for these discrepancies if the surgical description and judgment of the operator are deemed accurate and if the roentgenograms are properly labeled. It is our custom to identify the posterior surface of the sacrum early in the operation and to use this for orientation. The disc which is believed to be causing the difficulty is then examined and if this is found to be normal, the adjacent disc is examined. A disc is not removed unless it is found to be abnormal and is believed to be causing symptoms. In ten patients (1.8 per cent) no disc abnormality was found at surgery to explain a positive myelographic defect (Fig. 7).

TABLE III

DATA ON 660 PATIENTS WITH SIXTY-EIGHT MULTIPLE AND COEXISTENT RUPTURED DISCS

Three Coexistent Ruptured Discs			Two Coexistent Ruptured Discs		
Location of Disc	Sex of Patient		Location of Disc	Sex of Patient	
	Male (*Number*)	Female (*Number*)		Male (*Number*)	Female (*Number*)
L 3, L 4, L 5	4		L 2 and L 3	1	
			L 3 and L 4	8	3
			L 4 and L 5	40	12
Total	4		Totals	49	15

At times the myelogram indicated a mid-line rupture when, at operation, in the judgment of the surgeons, only a lateral disc rupture was found, or *vice versa*. This constitutes a minor discrepancy in the myelogram, because the correct level of the lesion was indicated to the surgeon but not the correct type of rupture; this occurred in twenty-five patients (4.5 per cent).

In Table III is shown the distribution of multiple ruptured discs encountered in this series. In the last group of 660 patients, multiple coexistent ruptured discs occurred sixty-eight times (10.3 per cent). Four men had such ruptured discs at each of the lower three lumbar intervertebral spaces, and they were shown by myelography and were removed at one operation. In the other patients each had two separate ruptured discs; these were more commonly encountered in males and more commonly located at the lower two lumbar levels (Fig. 8).

In the total series of 866 patients, three intradural and six extradural neoplasms (1 per cent) masquerading as lumbar disc lesions were encountered. Unfortunately, only two of the intradural lesions were definitely diagnosed before operation. Four of these neoplasms were in the early series of 206 patients. One intradural neurofibroma was revealed and diagnosed before operation by the myelogram, but three extradural neurofibromata were not. In the present series of 560 patients there were two cauda equina tumors. In the first patient the diagnosis was suspected from the myelographic appearance (Fig. 9), and a diagnosis of such a tumor was made by the roentgenologist. However, neurosurgical and neurological consultants felt that the myelographic findings were compatible with a ruptured disc and not with a cauda equina tumor.

At surgery, adequate findings to explain the myelographic defect were not found on exploration of the third, fourth, and fifth lumbar intervertebral disc spaces, and palpation of the dural sac exposed by hemilaminectomy was considered to be within normal limits. Upon opening of the dura, a soft neurilemoma arising from the root of the fifth lumbar nerve was found and later removed by the neurosurgeon. In the second patient the diagnosis was made from the myelogram (Fig. 10), and the patient was transferred to the neurosurgery service where an ependymoma arising from the filum terminale was removed.

Three additional patients had a history and physical examination indicative of a lumbar disc lesion. Routine lumbosacral roentgenograms were considered to be negative, and myelographic findings were also negative. At subsequent surgery after bone destruction had occurred, no abnormality of the disc was found, but metastatic carcinoma of the vertebrae was present. Odell and Key showed well how malignant bone tumors may simulate a lumbar disc syndrome.

Sixty-one patients (10.9 per cent) had more than one operation for a ruptured lumbar disc in this series of 560 patients because of recurrent symptoms;

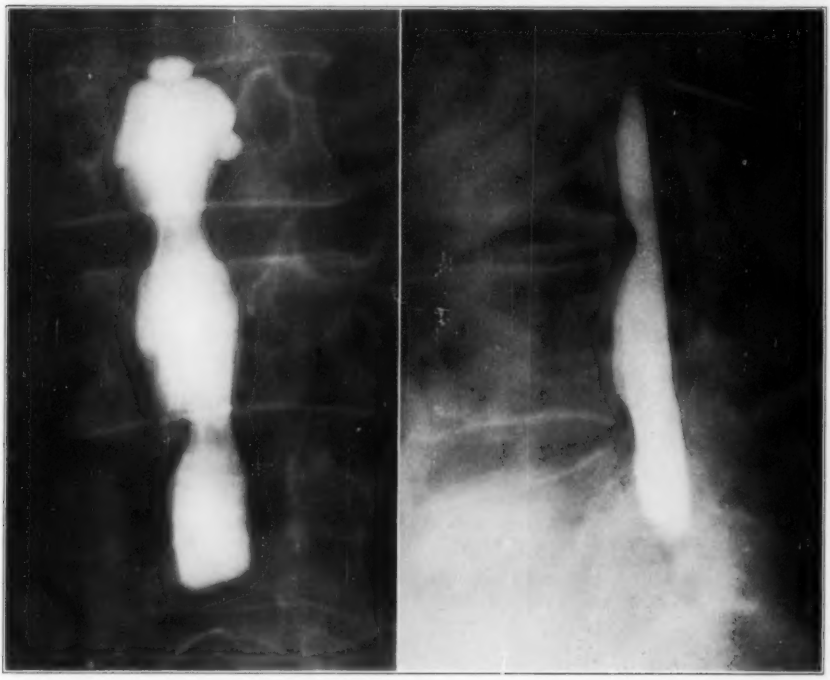

FIG. 8

The patient was a white man, sixty-three years old, who had had low-back pain for many years. The presenting complaint was pain subsequent to lifting an object and was associated with sciatica on the right side which gradually worsened. Physical examination showed a list to the left, tenderness over the levels of the fourth and fifth lumbar vertebrae, with reproduction of the sciatica on the right side, a positive straight-leg-raising test and decreased knee jerk on the right side, and no sensory change or motor weakness.

The myelogram showed an hourglass defect at the level of the fourth lumbar vertebra and an indentation type of defect at the level of the fifth lumbar vertebra on the right side. At surgery a bulging mid-line disc was removed from the right side at the level of the fourth lumbar intervertebral space, and a protruded disc was also removed on the right side from the level of the fifth lumbar intervertebral space. The myelographic and surgical findings of two ruptured discs were in accord.

there were nineteen females and forty-two males. Forty-eight of the recurrent disc ruptures were at the same level, and thirteen were at a different level or side. In the females, thirteen of the recurrent ruptures were at the same level and six were at a different level or side. In the males, thirty-five of the recurrent ruptures were at the same level and seven were at a different level or side. Four patients had surgery for disc symptoms three times.

Thirty-nine of the series of 560 patients (7 per cent) had spine fusion in addition to disc removal. This does not indicate a high percentage of fusion but is an increase over our earlier rate. We now tend to fuse when recurrent surgery is necessary, when marked instability is found, or when an isthmus defect is demonstrated.

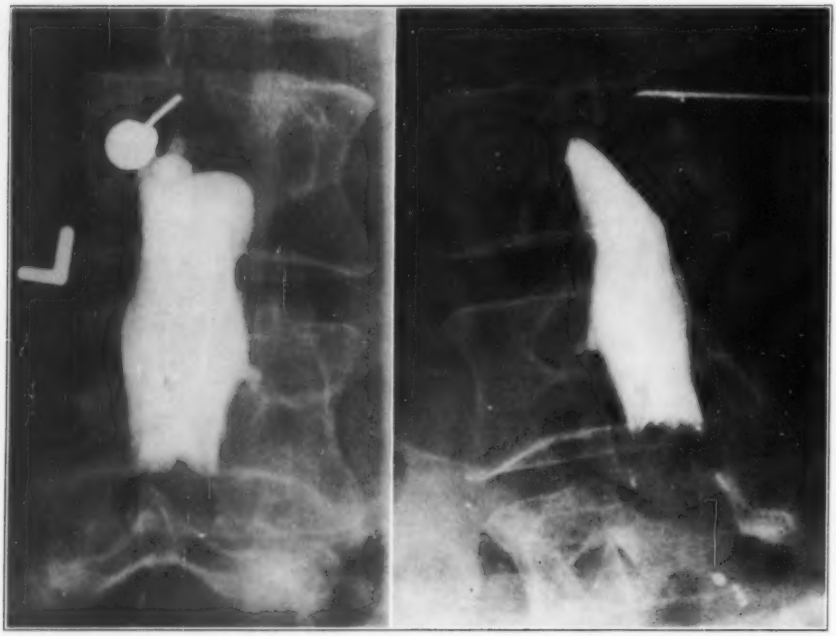

FIG. 9

The patient was a woman, fifty-one years old, who had sciatica on the right side of gradual onset which increased in severity and later became associated with low-back pain which was worse at night. Physical examination showed a slight list to the left, with a flattened lumbar-spine curve, tenderness over the fourth lumbar vertebra, a positive straight-leg-raising test and a decreased knee jerk on the right, and no sensory loss or motor weakness. The myelogram showed a complete block at the level of the fourth lumbar vertebra. At operation a neurosurgeon removed a neurilemoma arising from the root of the right fifth lumbar nerve. The myelographic and surgical findings were in accord.

COMPLICATIONS OF MYELOGRAPHY

Myelography is not without complications. Arachnoiditis [5], pulmonary emboli [9], and encystment of dye have been reported in the literature after myelography with pantopaque. Fortunately, these complications are rare and have not been encountered in this series. The most frequent complication noted in this series was headache, which was usually mild and controlled with bedrest and aspirin. Occasionally, the headache was severe enough to delay operation or discharge of the patient from the hospital. Although many of the patients had postmyelogram headaches, only 5 per cent had sufficient discomfort to have it recorded in the hospital record. Rarely, a sterile meningismus occurred but was always transient.

In one patient an extra-arachnoid injection of nine cubic centimeters of pantopaque spread along the nerve roots. Twenty-four hours after the attempted myelogram, nausea, vomiting, and rigidity of the abdomen developed. Because these symptoms simulated an acute condition within the abdomen, surgical consultation was requested. Observation confirmed the impression that the symptoms of peritoneal irritation were due to nerve-root irritation from the extra-arachnoid injection and spread of the dye along the nerve root. No complications or ill effects were noted after pantopaque dissemination along the nerve roots.

One fatality attributed to myelography occurred in a patient in whom a brain abscess developed secondary to pyogenic meningitis. A ruptured intervertebral disc had been removed under local anesthesia the day after the myelogram. The meningitis manifested itself late, and at autopsy the operative wound was

clean and healed, and the entire infection was confined within the subarachnoid space.

INDICATIONS FOR MYELOGRAPHY

The indications for myelography can be summarized as follows:

1. To establish the exact level and type of intervertebral disc lesion and to eliminate unnecessary exploration of normal intervertebral disc spaces;

2. To determine the possibility of multiple disc lesions;

3. To determine the presence or absence of a disc lesion when clinical evidence is uncertain or indefinite;

4. To try to establish the cause of recurrent symptoms in patients who have had a previous laminectomy;

5. To rule out the possibility of a spine or cauda equina tumor or other abnormality as a cause of the low-back pain.

Certainly, not every patient who has had low-back pain with or without sciatica should have a myelogram. In general, myelography should be considered for those patients who have a clinical diagnosis of a lumbar disc lesion which has been made after a careful history, complete physical examination, necessary laboratory studies, and a complete set of lumbosacral roentgenograms, and who have disabling symptoms which have failed to respond to an adequate trial of conservative treatment either as out-patients or in-patients. When a patient is a possible and suitable candidate for surgery for a lumbar disc lesion, we now believe that a myelogram should be a part of the preoperative study.

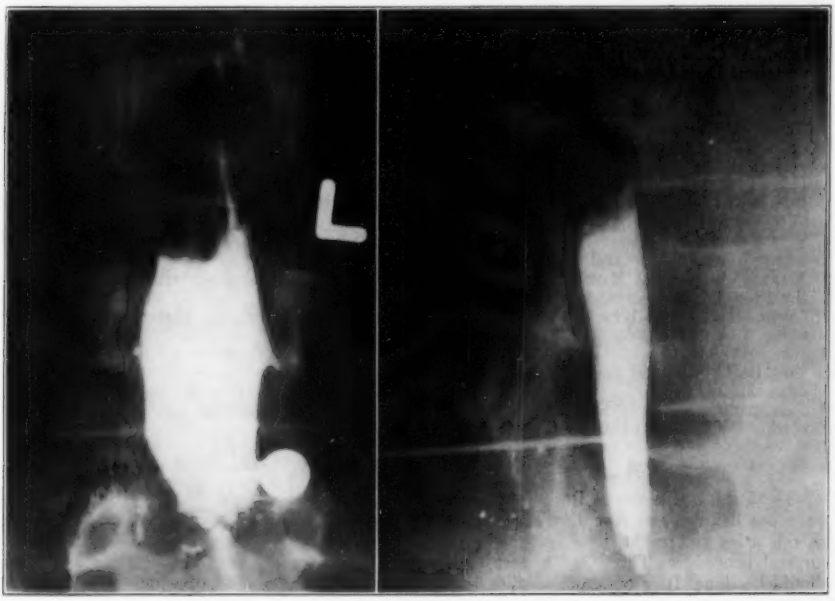

FIG. 10

The patient was a white woman, twenty-eight years old, who had pain of gradual onset in the coccygeal area and, later, low-back pain which was aggravated by lying down. During the fifth month of pregnancy the pain became worse and was associated with difficulty in voiding. After the spontaneous delivery of a normal infant, the low-back pain became much worse and was associated with weakness in the right leg. There were decrease of knee jerk on the right side, weak dorsiflexors of the right foot, and hypalgesia of the lower sacral dermatomes on the left side and over the lateral aspect of the right calf.

The myelogram showed a complete block at the level of the second lumbar vertebra, with a convex border. At operation the neurosurgeon removed an ependymoma arising from the filum terminale. The myelographic and surgical findings were in accord.

SUMMARY AND CONCLUSIONS

1. An analysis is presented of 866 patients who, during the past twelve and a half years, had myelography as part of the diagnostic study by the orthopaedic surgeons at Barnes Hospital for a lumbar intervertebral disc lesion; surgical exploration of the lumbar area was then performed.

2. At operation, 625 positive and thirty-seven negative myelograms were confirmed, giving an accuracy of 76.4 per cent.

3. Major discrepancies were noted in 150 (17.3 per cent) cases.

4. Relatively unimportant or minor discrepancies were present in fifty-four cases (6.2 per cent).

5. Six extradural and three intradural neoplasms masquerading as ruptured intervertebral disc lesions occurred in this series of 866 patients, representing an incidence of 1 per cent. Even with myelograms only two intradural tumors out of the total of nine neoplasms were diagnosed definitely before operation.

6. In cases in which operation for a lumbar disc lesion is clearly indicated on the basis of the clinical picture and lack of response to conservative treatment, a negative myelogram should not prevent the surgeon from exploring the lumbar spinal canal.

7. Myelography can be a valuable aid in diagnosis and may be very helpful in borderline cases. We now believe that myelography should routinely precede surgery for lumbar disc lesions.

8. In our opinion a lumbar myelogram should not be done when a ruptured lumbar intervertebral disc is suspected unless surgical treatment is being considered.

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DISCUSSION

Dr. Paul P. Lipscomb, Rochester, Minnesota: In writing about protruded intervertebral discs, our beloved and recently deceased Ralph K. Ghormley stated, and I quote, "In deciding on operative treatment, it is recognized that there are a good many ways to carry out any surgical procedure. There are honest and justifiable differences about how such operations should be done. It is our opinion that there are several methods, all of which are good. The choice of procedure by any surgeon is dependent upon his experience and training."

I believe that if there were any one means of diagnosis and surgical treatment for the protruded intervertebral disc which was better than all others, each of us would be using this method, and other methods would soon be forgotten. I can only agree with Dr. Lansche and Dr. Ford, who now conclude that myelography should routinely precede surgery for lumbar disc lesions, and admit that myelography can be a valuable aid in diagnosis and be a decisive factor in borderline cases. I am glad to hear about the group of which they speak.

Dr. J. Neill Garber, Indianapolis, Indiana: Our technique of myelography and indications for it are identical to those of Lansche and Ford. We use nine cubic centimeters of pantopaque

(Continued on page 288)

Congenital Dislocation of the Knee*

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Congenital dislocation of the knee is a relatively rare deformity. According to Clayburgh and Henderson only two cases of congenital dislocation of the knee were seen at the Mayo Clinic in 1955, as compared with seventy-four cases of congenital dislocation of the hip seen in 1953. During the past twenty-five years we have seen only twelve patients with congenital dislocation of the knee, compared with several hundred patients with dislocated hips.

The deformity commonly involves both knees. Seven of our twelve patients had bilateral dislocation; nine of the twelve patients were female.

ETIOLOGY

The theory that some mechanical factor is paramount in producing this deformity has had many adherents. The mechanical factors have been considered to be trauma to the mother, lack of amniotic fluid, lack of intra-uterine space, or malposition of the fetus.

It has been suggested by others that *in utero* the feet may become locked beneath the mandible or that one foot may become locked in the axilla, hyperextending the knee and producing subluxation or dislocation (Fig. 1).

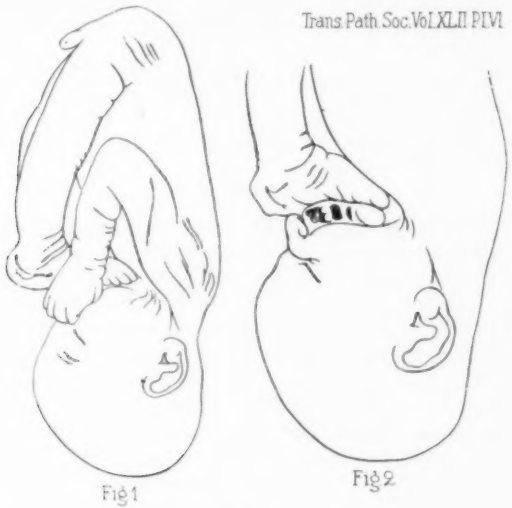

FIG. 1

A stillborn infant with bilateral anterior dislocation of the knee and a deformed mandible. (Reprinted from "Genu Recurvatum in a Foetus at Term" by S. G. Shattock. Trans. Pathol. Soc. London, 42: 280-292. London, Smith, Elder and Co., 1891.)

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 4, 1958.

At least three of our twelve patients were delivered by breech presentation. Previously reported cases show the incidence of breech presentation to be higher in patients with congenital dislocation of the knee than the usually expected 3 to 4 per cent in the general population. Vartan stated that extension of the leg is the prime factor in preventing spontaneous cephalic version and thus causing persistence of the breech position to term.

Duraiswami pointed out that adverse environmental influences can give rise to developmental anomalies indistinguishable from those of genetic origin.

Deformity of the distal femoral epiphysis has been considered important in causing the subluxation, allowing the tibia to slide forward on the deformed femoral epiphysis. Deformity of the epiphyses around the knee occurred in our older, but not in our younger, patients suggesting that the deformity may be a secondary change similar to that seen in the femoral head in older patients with untreated dislocation of the hip. Clinically, the dislocations do not resemble those produced by trauma; thus, trauma to the fetus is an unlikely etiological factor.

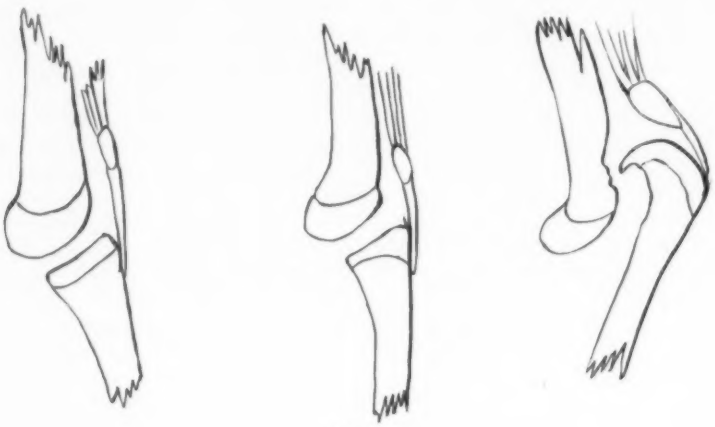

FIG. 2

Drawing to show different degrees of subluxation and dislocation.

Certain investigators stated that the essential abnormality is not a dislocation but a contracture of the quadriceps muscle of the knee in the hyperextended position. Middleton, after observing fibrosis and atrophy of the quadriceps muscle concluded that the deformity was due to contracture of the quadriceps—as in arthrogryposis multiplex congenita. In one of our patients, J.N.T., the rectus femoris was found to be fibrotic and atrophic. In patient D.S. the quadriceps tendon was fixed to a mass of fibrous tissue in the area normally occupied by the suprapatellar pouch. However, this may be the result, rather than the cause, of the deformity. Arthrogryposis multiplex congenita characteristically causes flexion contractures and extensive involvement, rather than fibrosis of only one muscle.

The importance of heredity is difficult to determine, since family histories, for various reasons, are often inaccurate. Two of our twelve patients had a family history of what seemed to be a similar deformity.

A review of the literature shows that in congenital dislocation of the knee, the incidence of other congenital abnormalities is high not only in the patient himself, but in the family as well. McFarlane reported an interesting situation of a woman with untreated congenitally dislocated knees who had three children by three different fathers. The first child had dislocated knees; the second had dislocated knees, bilateral club-foot, a cleft palate, and abnormal toes; and the

third child had dislocated knees. The mother had, in addition to dislocated knees, bilateral coxa valga, scoliosis, hyperextension of the elbows, and abnormal toes. The fathers had no evident abnormalities.

Spina bifida, hydrocephalus, mongolism, cryptorchism, angiomata, facial paralysis, imperforate anus, and dislocation of the elbow have been reported in patients with congenital dislocation of the knee. Congenital dislocation of the hip, especially, occurs with considerable frequency; it was present in six of our twelve patients. One might expect the development of the dislocated knee to be related to the same factors that produce other congenital abnormalities.

FIG. 3

FIG. 4-A

Fig. 3: D.F., a boy, two and one-half years old. This patient had untreated dislocations of both hips and both knees; the photograph illustrates his quadruped type of gait.

Fig. 4-A: L.L.C. Anterior dislocated knees demonstrating hyperextension and deep transverse anterior skin folds. The femoral condyles are prominent posteriorly.

PATHOLOGY

The characteristic deformity in congenital dislocation of the knee is anterior displacement of the tibia in relation to the femur. Rotatory and lateral subluxation may also occur to a lesser or to a greater degree.

The term *genu recurvatum* should be reserved for those deformities—muscle imbalance, epiphyseal arrest, and malunion—that produce hyperextension of the knee. The term *congenital subluxation* or *dislocation of the knee* should be used to designate those congenital deformities with hyperextension of the knee and anterior displacement of the tibia.

It is probable that the degree of deformity in the knee varies, much as it does in congenital deformities of the hip where there are gradations represented by acetabular dysplasia, minimum subluxation, and gross dislocation with marked involvement of all articular and periarticular structures. In the majority of patients the deformity in the knee is a subluxation rather than a dislocation (Fig. 2).

Clinically, the deformity is immediately apparent since the afflicted knee is usually hyperextended 10 to 20 degrees and may be further extended so that the toes touch the chest. In those patients with severe hyperextension deformity, flexion is not possible, and if it is attempted the knee immediately springs back into hyperextension. There are prominent transverse folds in the skin across the front of the knee incidental to the hyperextension deformity. The femoral condyles

are prominent in the popliteal space. In only one of our patients would the knee dislocate while flexed—the right knee of D.S. This must be rather unusual (Figs. 7-A and 7-B). It is interesting to note that when the dislocation is complete and of long standing the hyperextension deformity is lost (Fig. 11-A).

As stated previously, the tibia is subluxated or dislocated forward. There may be rotatory deformity, lateral displacement of the tibia, and valgus deformity of the knee. Anterior bowing of the tibia has been noted. The hamstrings, particularly on the medial side, may be displaced forward and actually act as extensors of the knee. This was particularly striking in the right knee of D.S., where the hamstrings actually snapped anteriorly and posteriorly as the child extended and flexed his knee.

The pathological changes, which have been described in the structures around the knee in older patients, are probably adaptive modifications. The patella may not be palpable because it is undeveloped and displaced proximally to an area where it is less prominent. In patient J.T. it was found displaced into the supra condylar area and embedded in fibrous tissue. In patient D.S. the patella was not actually embedded in fibrous tissue in the left knee. Instead, it articulated with a mass of fibrous tissue in the suprapatellar area. In the right knee the femoropatellar articulation was normal, but both knees were dislocated.

Dissected specimens have shown that the heads of the gastrocnemius may be displaced laterally or distally. The semimembranosus muscle has also been found by Bacilieri to be displaced laterally, a displacement which he considered to be the result of the abduction deformity of the knee.

The popliteal nerves and vessels are not compromised in these cases, which is indicative that this is a slowly developing deformity. In all of our patients the popliteal vessels were palpable in the posterior intercondyloid area, and the circulation was normal.

Kaijser found the distal epiphysis of the femur to be posterior to the longitudinal axis of the femur in these cases, a point which we were unable to verify on reviewing our roentgenograms. In the older patients, M. H. and G. S., there were adaptive changes in all the bones of the knee (Figs. 10-C and 11-A).

FIG. 4-B FIG. 4-C

Roentgenograms of the untreated dislocated knees.

Usually, little is said about the joint capsule in the descriptions of dissected specimens, except to note that when the capsule is sectioned transversely, the knee may be flexed.

In the patients on whom we have operated, we have been impressed by the shortening of the anterior capsule and by its proximal attachment to a mass of fibrous tissue in what would correspond to the suprapatellar pouch. The anterior displacement of the collateral ligaments and the shortened anterior portion of the capsule prevented reduction of the dislocation, even when the quadriceps mechanism was transsected. In the left knee of D.S. there was no space anterior to the femoral condyles into which they might slide as the knee was flexed—the suprapatellar pouch being absent. The dislocation could not be reduced until the capsule was freed at its supero-anterior attachment and reflected over the sides of the condyles as the knee was brought into flexion. All patients had lateral instability of the dislocated knee since the collateral ligaments were displaced anterior to the femoral condyles. As in our twelve-year-old patient, G. S., the anterior cruciate ligaments were found to be elongated and thickened. This ligament probably is one of the main factors contributing to the stability of the knees of our patient, M. H., a woman sixty-seven years old, with untreated, severe dislocations. In severe deformities the hamstrings are displaced anterior to the femoral condyles and act as knee extensors.

FIG. 5-A

M.L.W. This photograph, made at birth, shows the degree of hyperextension of the knee.

TREATMENT AND PROGNOSIS

It is apparent from the literature and from our own experience that many congenital dislocations of the knee, if seen shortly after birth, can be treated simply by manipulation and immobilization. Reduction is effected by flexion of the knee, and the extremity is then immobilized with the knee in flexion until it becomes stable in the reduced position. Of the nineteen dislocations in the twelve patients included in the series, four were treated successfully by this method.

If an immediate manipulative reduction is not possible, a preliminary period of traction followed by manipulation and immobilization in plaster may be successful. Six knees in this series were treated in this manner. In two the manipulation was carried out with the patient under general anesthesia. Skeletal traction with a Kirschner wire through the proximal part of the tibia with the patient in the prone position was most effective since this produced both distraction and flexion, the forces needed to reduce the dislocation (Fig. 9). The pin and traction bow were incorporated in a short plaster boot. The foot of the bed was elevated on four-inch shock blocks, and two or three pounds of traction was applied over an overhead pulley. Rotational and valgus deformities could be

FIG. 5-B

FIG. 5-C

Fig. 5-B: Anteroposterior roentgenogram of right knee with congenital dislocation.
Fig. 5-C: Lateral roentgenograms of both knees in full extension show that the right knee hyperextends and subluxates, whereas the left knee cannot be fully extended.

corrected by changing the direction of the traction. The corrective force could be increased by applying a band across the back of the thighs and gradually elevating the traction pulley. The traction was released during feeding.

The period of immobilization after reduction by traction and manipulation varied from two months for patient L.G. to eight months for one knee of patient L.L.C.

An open reduction is indicated when closed methods fail. It was necessary to operate on six knees of four patients in this series. Another patient, C.P., was also a probable candidate for open reduction of both knees. It was evident that in those knees fixed in hyperextension mere lengthening of the quadriceps mechanism was not sufficient to permit reduction; it was also necessary to incise transversely the anterior capsule of the knee. As an alternative to this, the quadriceps tendon, patella, and patellar tendon (left knee of D.S.) were first isolated from the capsule by parapatellar incisions, then split longitudinally and lengthened by a tenotomy (Figs. 7-E and 7-F). The shortened anterior capsule was then reflected from its abnormal anterior insertion and allowed to slide posteriorly as the knee was placed in flexion. This brought the hamstrings and collateral ligaments into their proper relationships to the knee. The quadriceps mechanism was sutured in its lengthened position, and the subcutaneous tissue and fascia were sutured over the front of the knee. If the quadriceps tendon or patella is fixed in fibrous tissue it must, of course, be dissected free.

If the knee is of the unstable variety which is easily reduced but which dislocates even in flexion (right knee, D.S., Fig. 7-C), reduction may be maintained by advancing the tibial attachment of the elongated anterior cruciate ligament to the anterior edge of the tibial plateau. If the reduction is unstable, small Steinmann pins may be placed across the joint to ensure maintenance of the reduction until the ligament has healed. The pins are, of course, cut off beneath the skin and removed in several weeks.

Care must be taken not to advance the anterior cruciate ligament too far anteriorly since this will produce a flexion deformity.

In this series the prognosis was best for the knees that did not have open reductions, especially those treated soon after birth with easy reductions that did not require anesthesia. Since these knees represent the less severe deformities, the prognosis would be expected to be better. All of the patients treated by closed methods have done well. Too few open reductions have been done to permit any generalizations regarding results after surgical treatment, but it might be

anticipated that some of these knees will have some instability and perhaps lack full active extension. No one operative procedure is a panacea. The pathological changes in this anomaly may be as varied as those in congenital dislocation of the hip. The surgical procedure must be varied to cope with the abnormalities found in each knee.

In older patients who have sufficient disability referable to a congenitally dislocated knee, arthrodesis may be indicated. Patient G.S., a girl, twelve years old, was incapacitated by an unstable knee, the result of an untreated congenital dislocation (Figs. 10-A, 10-B, and 10-C). The only form of treatment applicable here was arthrodesis since even if the dislocation could have been reduced, the joint surfaces were too incongruous to permit useful function. However, it should be noted that patient M.H., a woman, sixty-seven years old, had severe dislocations of both knees. Despite this she had earned her own living and was able to walk quite well. Obviously, she was much better off than she would have been if her knees had been arthrodesed or if open reductions had been attempted late in childhood (Figs. 11-A and 11-B).

FIG. 5-D

The patient at five years of age.

CASE REPORTS

D. F., a white boy, born in May 1937, was seen soon after birth. A diagnosis was made of congenital dislocation of both knees and congenital dislocation of the right hip. The knees were dislocated and fixed in hyperextension.

The child disappeared from the clinic before treatment was instituted but was readmitted to the hospital when he was two and a half years old. At that time he got about with a peculiar quadruped type of gait, as illustrated in Figure 3. Both dislocations were resistant to manipulation.

Roentgenograms showed complete anterior dislocations of the tibiae in relation to the femora, as well as lateral and external rotatory displacement of the right tibia in relation to the right femur. The right hip was dislocated.

Since this boy's deformities were resistant to conservative measures, open reductions were performed on both knees and the right hip. A final evaluation cannot be made because the boy died one year later, after an unrelated surgical procedure. At that time both knees were reduced.

This case is an example of severe bilateral deformity associated with congenital dislocation of one hip. It is probable that both the severity of the deformities and the age at which treatment was instituted necessitated the open reduction.

L. L. C., a white girl, six months old, was admitted to the hospital on May 31, 1944, because of deformed legs and a cleft palate present since birth.

One paternal uncle wore a brace and was said to have congenital dislocation of the knee.

The mother had some vaginal bleeding during the first four months of pregnancy, but the pregnancy was otherwise uncomplicated. Delivery was not by breech presentation.

At six months of age the infant's knees were held in 10 degrees of hyperextension and could not be flexed. The femoral condyles were prominent in the popliteal fossae, the patellae

were not palpable, and there was no abnormal rotation of the knees. Deep transverse folds indented the skin across the front of the knees. When an attempt was made to flex the knees passively, they sprang back into the hyperextended position (Figs. 4-A, 4-B, and 4-C). Roentgenograms showed subluxation of both knees.

With the child in the supine position, traction was applied to the lower extremities for two weeks, but there was no improvement of the deformity. Traction was then applied to the lower extremities with the patient in the prone position; in four days, knee flexion was possible to 110 degrees. The traction was continued for one month, being released for feedings and bathing.

With the infant under anesthesia, the dislocations of the knees were reduced by manipulation, and toe-to-groin casts applied with the knees in flexion. After a period of five months, during which time the casts were changed three times, immobilization of the left knee was discontinued since the deformity of this joint was considered to be corrected. Immobilization of the right knee in flexion was continued for three more months.

The girl was re-examined when she was two years old; at that time there was slight anteroposterior instability and slight valgus deformity of the left knee. The girl, however, had excellent quadriceps power and walked without a limp. There was a complete range of knee motion. The normal relationships between the tibiae and femora were shown by roentgenograms. Further treatment was considered unnecessary.

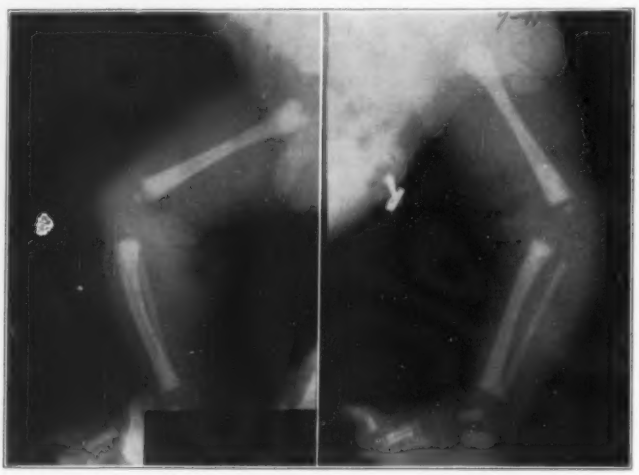

FIG. 6-A FIG. 6-B

L.C.G. Roentgenograms of the right knee in maximum flexion and hyperextension showing subluxation.

J. N. T., a white female infant, twenty-one months old, was admitted to Stanford University Hospitals on August 15, 1948.

There was no history of congenital abnormality in the family.

The infant was delivered by breech presentation. At birth it was noted that her knees were held in the hyperextended position and would not flex. Before entering Stanford University Hospitals, she had been treated intermittently by manipulation, traction, and casts. At the age of twenty-one months she began to walk with a right-sided limp, elevating the right pelvis to swing the right leg through. The right knee was hyperextended and would passively flex only 15 degrees. The left knee appeared normal and could be actively flexed to 90 degrees. The femoral condyles were palpable in the right popliteal fossa. There was a marked anterior bowing of the right tibia, probably because of a healed fracture resulting from manipulation.

Roentgenograms showed the right knee to be held in 20 degrees of hyperextension. The anterior tibial bowing amounted to 50 degrees. The right tibia was subluxated anteriorly and externally rotated in relation to the femur. The relationship of the bones of the left knee was normal.

Traction to the right lower extremity in the extended position was tried unsuccessfully for one month. Therefore, capsulotomy and quadricepsplasty was done on the right knee through a longitudinal incision. The patella was found to be bound down in fibrous tissue in the supracondylar area. An anterior transverse capsulotomy alone did not allow reduction of the dislocation, and it was necessary to split the patella, the ligamentum patellae, and the quadriceps tendon longitudinally, lengthening the entire mechanism. The rectus femoris

FIG. 7-A

FIG. 7-B

Fig. 7-A: D.S. Roentgenogram of the right knee in flexion showing dislocation.
Fig. 7-B: Right knee. The dislocation was reduced by manual traction.

was found to be atrophied and fibrotic. The medial hamstrings were displaced forward; however, they resumed their normal positions when the knee was placed in flexion. After operation the right knee was immobilized in a cast in 55 degrees of flexion.

The immobilization was continued for five months. Since there was little quadriceps power and much lateral instability in the knee, a toe-to-groin brace was then employed for one year.

When the patient was re-examined at the age of ten years, she walked well with no limp. There was an obvious residual anterior bowing of the right tibia, some atrophy of the right thigh, and slight lateral instability in both knees. The range of active motion of the left knee was from 190 to 90 degrees; the right knee from 165 to 75 degrees. The right knee, however, could be passively extended 10 more degrees. There was no inequality of leg length.

Roentgenograms made on January 31, 1957, showed normal relationships between the femora and the corresponding tibiae. The right patella was small and divided longitudinally, obviously the result of the old osteotomy. The joint spaces were well maintained. The patellofemoral joint functioned normally. The anterior bowing of the right tibia was now located in the middle third of the shaft, having moved in a distal direction with growth.

C. J. Y., a Chinese girl, four months old, was seen at Stanford University Hospitals on November 5, 1948, for evaluation of congenital dislocation of the left knee. The mother's pregnancy was normal, and delivery was not by breech presentation. There was no history of congenital abnormality in the family.

At birth it was noted that the left knee could be hyperextended so that the infant's toes touched the abdomen above the hip. Roentgenograms showed anterior dislocation of the left knee. The dislocation was reduced by manipulation, and the knee immobilized in slight flexion in a toe-to-groin cast the second day after birth. Immobilization lasted for six months.

An examination made on July 23, 1953, when the child was five years old, showed that both knees would hyperextend 30 degrees and would flex completely. There was some antero-

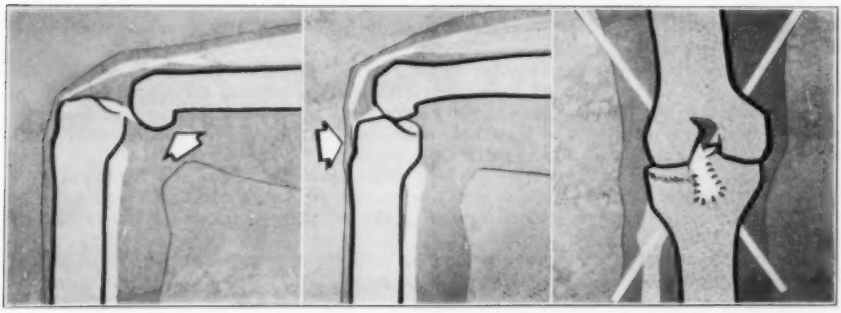

FIG. 7-C

Drawings showing advancement of the anterior cruciate ligament and temporary fixation of the joint in the reduced position with crossed Kirschner wires.

were not palpable, and there was no abnormal rotation of the knees. Deep transverse folds indented the skin across the front of the knees. When an attempt was made to flex the knees passively, they sprang back into the hyperextended position (Figs. 4-A, 4-B, and 4-C). Roentgenograms showed subluxation of both knees.

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FIG. 7-A

FIG. 7-B

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Fig. 7-B: Right knee. The dislocation was reduced by manual traction.

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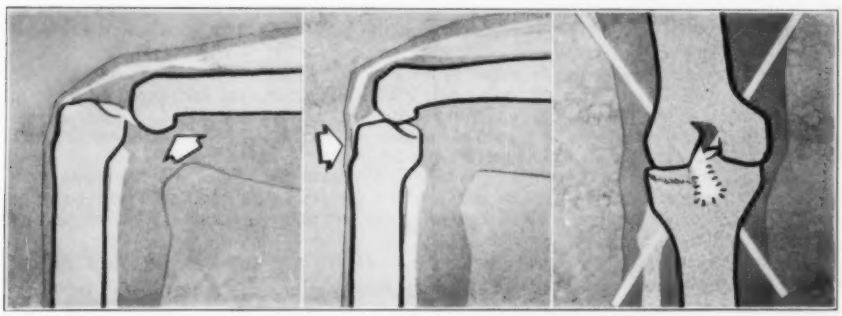

FIG. 7-C

Drawings showing advancement of the anterior cruciate ligament and temporary fixation of the joint in the reduced position with crossed Kirschner wires.

FIG. 7-D

Left knee. This severe dislocation did not respond to traction, and reduction was necessary.

posterior instability in flexion in both knees, but in the extended position they were stable. The family later reported that when the child was nine years old she had a complete range of motion in her knees and was in no way disabled.

M. L. W., a white female infant, was delivered by the left occipito-anterior position at Stanford University Hospitals on December 9, 1952.

A paternal aunt had had a congenital abnormality of the knee, which had been corrected by cast immobilization.

The mother's pregnancy and delivery were uncomplicated. It was noted at birth that the infant's right knee was maintained in 30 degrees of hyperextension. Passive flexion was possible to 90 degrees. The femoral condyles were prominent in the popliteal fossa, and the tibia was displaced forward in relation to the femur. The patella was not palpable (Figs. 5-A through 5-D). Roentgenograms of the knees showed the right tibia to be subluxated forward on the femur. The right knee was hyperextended 30 degrees. The left knee could not be extended to 180 degrees.

The subluxation was easily reduced by flexing the knee to 90 degrees and maintaining it by a plaster cast. The cast was changed three times, the immobilization being discontinued after five and a half months.

When the child was last examined at the age of four years she walked and ran without evidence of abnormality. Both knees hyperextended 20 degrees and had a full range of flexion. There was the usual degree of ligamentous laxity seen in children of this age. The left knee was in slight valgus position.

There was no inequality of leg length. Roentgenograms of the right knee made on January 28, 1956, showed no abnormality.

P. R., a white girl, one of twins, was born in April 1955. Delivery was by breech presentation. The other twin was normal, and there was no family history of any congenital abnormality.

At birth it was evident that there was limited abduction of the hips, and hyperextension of 15 degrees of both knees. Roentgenograms showed that both the hips and the knees were dislocated.

Treatment consisted in traction applied to both knees for two and a half months, after which a cast was applied with the knees in the flexed position. One hundred and thirty-five degrees of flexion was attained. Treatment was then discontinued because the family moved out of the state.

A follow-up report indicated that the girl's knees flexed to 90 degrees, but at that time she was still immobilized in plaster because of the dislocated hips.

L. C. G., a Negro boy, was born by vertex delivery at Stanford University Hospitals on September 11, 1955. The mother's pregnancy was uncomplicated, and there was no familial history of congenital abnormality.

The right knee was found to be hyperextended to 45 degrees, but it could be manipulated into 90 degrees of flexion. The left knee could not be hyperextended and easily flexed from 170 to 30 degrees. The femoral condyles protruded into the right popliteal fossa. There were abnormal transverse skin folds over the anterior surface of the right knee. Metatarsus varus and internal tibial torsion were also present on the left.

Roentgenograms showed that the right knee hyperextended approximately 49 degrees and flexed to 90 degrees. In the hyperextended position the tibia was subluxated anteriorly. In contrast, flexion and extension roentgenograms of the left knee demonstrated no subluxation (Figs. 6-A and 6-B).

Without anesthesia being given a toe-to-groin cast was applied two days after birth, and the right knee was immobilized in 110 degrees of flexion. The immobilization was discontinued after two months.

At one year of age the child could walk with light support. There was a full range of motion in both knees, from slight hyperextension to full flexion. The right knee hyperextended a few degrees more than the left. There was no instability in either knee. Leg length was equal.

Slight tibial torsion and metatarsus varus persisted in the left limb. Roentgenograms of the knees, made on September 21, 1956, showed them to be normal.

This case demonstrates that a subluxated knee, which is reduced easily without anesthesia, can be treated effectively simply by immobilization in a cast for two months.

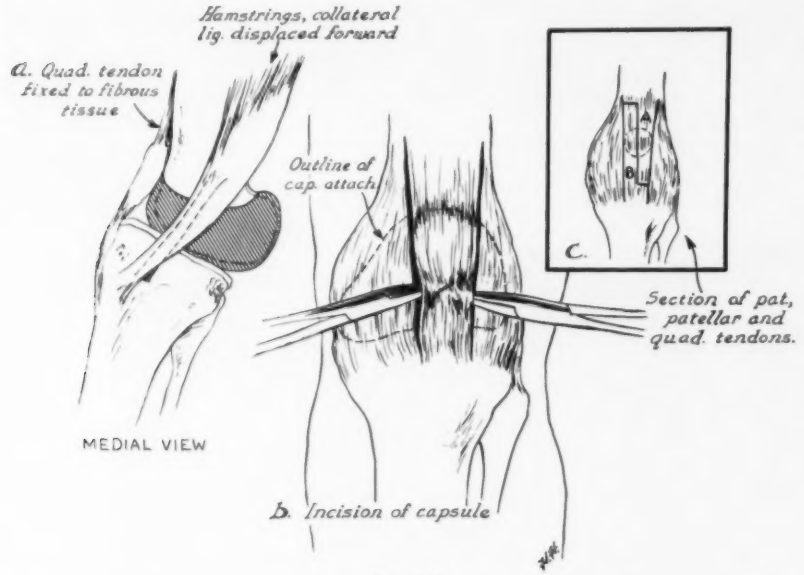
Hamstrings, collateral lig. displaced forward
a. Quad. tendon fixed to fibrous tissue
Outline of cap. attach.
Section of pat, patellar and quad. tendons.
C.
MEDIAL VIEW
b. Incision of capsule

FIG. 7-E

Figs. 7-E and 7-F: The technique of the open reduction.

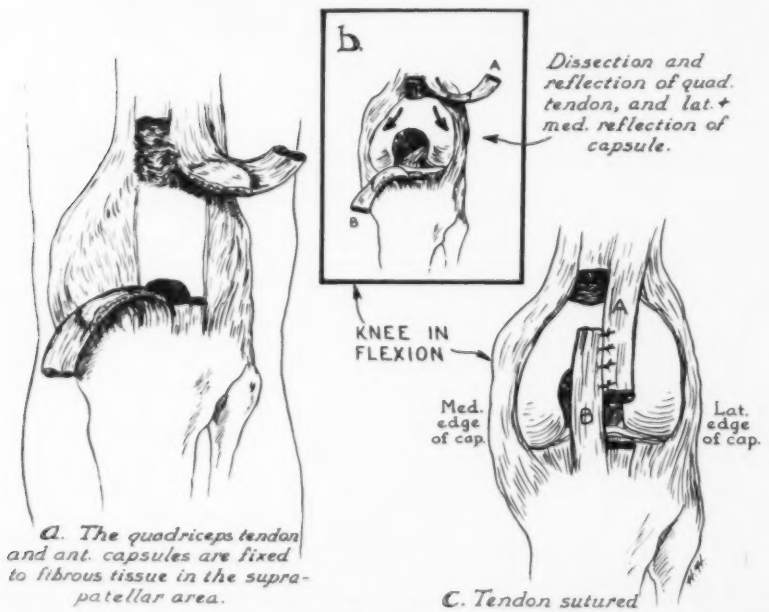
b.
Dissection and reflection of quad. tendon, and lat. + med. reflection of capsule.
KNEE IN FLEXION
Med. edge of cap.
Lat. edge of cap.
a. The quadriceps tendon and ant. capsules are fixed to fibrous tissue in the supra-patellar area.
c. Tendon sutured

FIG. 7-F

R. H., a white girl, was born by breech presentation on October 10, 1956. The birth weight was five pounds, ten ounces. The mother's pregnancy was uncomplicated. There was no familial history of congenital abnormality.

At birth it was found that the infant's right knee was hyperextended and would not bend. A diagnosis was made of congenital dislocation of both hips and of the right knee, but no treatment had been instituted except for manipulations of the knee by the mother, which gradually produced some flexion. The right foot was in marked calcaneus position at birth; this also had improved with manipulation by the mother.

Examination of the infant at Stanford University Hospitals when she was four months old disclosed asymmetry of her head. The left leg appeared to be shorter than the right. The right knee was in 15 degrees of valgus and 45 degrees of external rotation. The right medial femoral condyle was prominent in the popliteal fossa. Passive motion in the right knee was from 200 to 140 degrees and in the left, from 170 to 45 degrees. There was medial instability of both knees, but no abnormal anteroposterior instability. The right foot was held in calcaneus position, but plantar flexion was possible.

The right knee was reduced successfully by repeated manipulations and immobilization in flexion in a plaster cast. Attempts at closed reduction of the hips were unsuccessful, and open reductions were performed. At three years of age all three dislocations were reduced, and the child was walking with a normal gait. There was a normal range of motion in the right knee at that time.

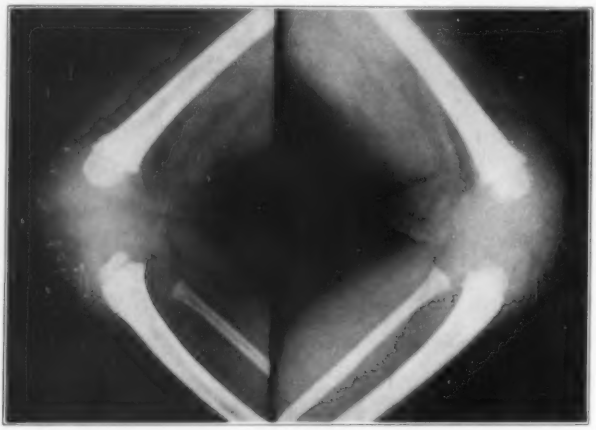

FIG. 7-G

Both knees, two years after open reduction.

D. S., a white boy, was born on May 19, 1957, by normal delivery. The birth weight was nine pounds, four ounces. The mother's pregnancy was normal. There was no familial history of congenital abnormality.

At birth it was found that both hips and both knees were dislocated, and there were severe calcaneovalgus deformities of both feet.

The usual findings associated with dislocation of the hips were seen when the infant was examined. The feet could be easily manipulated into the corrected position. The right knee was unstable. The tibia subluxated forward as the child flexed and extended his knee. This anterior subluxation of the tibia occurred even with the knee in flexion and was accompanied by a sliding of the hamstrings anterior to their usual position over the condyles of the femur. The range of motion in the knee was normal.

The left knee had a fixed hyperextension deformity of 220 degrees and would further hyperextend to 260 degrees. The femoral condyles were prominent in the popliteal area. The tibia was externally rotated and dislocated anterior and lateral to the femur. The popliteal artery was palpable in the intercondylar groove. A deep transverse groove was present in the skin and subcutaneous tissue of the suprapatellar region.

A Kirschner wire was placed through the shaft of the left tibia just distal to the anterior tibial tuberosity. Both feet were manipulated and maintained in the corrected position in plaster boots. The dislocation of the right knee was reduced by manipulation, and the cast extended up to the groin to hold the knee in flexion.

With the child in the supine position, three pounds of traction was placed on the Kirschner wire in the left tibia, the wire having been incorporated in the plaster boot. Some correction was obtained after forty days of traction, but the knee could still be flexed to only 170 degrees, even with the child under general anesthesia.

FIG. 8-A

A girl, six months old, with bilateral dislocated knees, hips, and elbows; bilateral club-foot and club-hand; and a congenital deformity of the mandible.

On August 13, 1957, an open reduction of the left knee was done utilizing an anterior longitudinal incision over the front of the knee (Figs. 7-E and 7-F). The patella, quadriceps tendon, and patellar tendon were freed from the surrounding capsule by parapatellar incisions. The extensor mechanism was then lengthened by double-L tenotomy, splitting the patella longitudinally.

The suprapatellar pouch was filled with fibrous tissue, which was adherent to the quadriceps tendon and to the adjacent capsule. This fibrous tissue actually fixed the capsule to the anterior surface of the femur at an abnormally low level. Even after the tenotomy, it was impossible to flex the knee fully because of the shortness of the anterior capsule and the forward displacement of the capsular structures and hamstrings in relation to the condyles of the femur. There was no space within the anterior portion of the capsule into which the femoral condyles could move during flexion of the knee. It was not until the capsular structures were reflected back on both sides of the femur that the dislocation could be reduced by flexing the knee and displacing the tibia backward beneath the femur.

FIG. 8-B

Roentgenogram of the right knee showing severe dislocation.

The anterior cruciate ligament was found to be elongated, but its tibial attachment was not advanced. The visible portions of the semilunar cartilages were normal. The femoral condyles appeared slightly more flattened than normal and the facies patellaris femoris was not well developed.

The quadriceps mechanism was also dissected away from the fibrous tissue in the suprapatellar area. With the knee in 60 degrees of flexion, the quadriceps and patellar tendons were sutured in their lengthened position with interrupted chromic catgut sutures. The medial and lateral portions of the capsule were allowed to remain in their new positions so that the two parapatellar incisions in the capsule of the front of the knee remained open. When the wound was closed these capsular incisions were covered only by subcutaneous tissue and skin.

The hips were manipulated and immobilized in abduction in a double hip spica cast with the knees in 60 degrees of flexion. Satisfactory positions of the hips were not maintained, and in November 1957 open reductions of both hips were done.

Despite persistent immobilization in flexion, the right knee continued to dislocate. Open reduction of this knee was done on June 13, 1958, through a median parapatellar incision. The configurations of the cartilaginous surfaces of the patella, femur, and tibia were normal, as were the semilunar cartilages. The quadriceps tendon, patellar tendon, and capsule were normal in contrast to the left knee. The anterior cruciate ligament was thickened and elongated, allowing the tibia to dislocate anteriorly when the knee was extended. The dislocation was reduced, and the reduction maintained by fixation of the joint in 90 degrees of flexion with two Kirschner wires, which were passed through the tibia and femur. The anterior cruciate ligament was shortened by freeing it at its distal end and suturing it to the periosteum

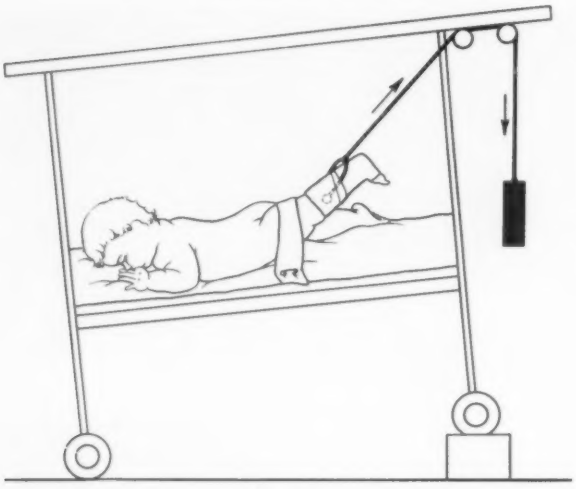

FIG. 9

The method of traction used successfully in the treatment of six knees in this series.

on the front of the tibia. The wound was then closed, and a hip spica was applied. The pins and cast were removed two months later (Figs. 7-A, 7-B, and 7-C).

When the child was re-examined on September 3, 1959, his right knee flexed to 152 degrees, but lacked 16 degrees in extension; his left knee flexed to 120 degrees, but lacked 8 degrees in extension.

At the time of writing, both hips and both knees are reduced and motion is increasing in the knees. The major problem now is the calcaneovalgus deformities of the feet.

An unusual situation was encountered in this patient. One knee, the left, could not be reduced initially without surgery, whereas the other knee could be reduced easily by manipulation but the reduction was not maintained despite prolonged immobilization. The right knee then required open reduction. The gross pathology of the two knees was strikingly different. In retrospect, surgery should have been utilized earlier in the treatment of the right knee.

G. S., a white girl, was born in 1946 by normal delivery. Examination at birth showed the right hip and left knee to be dislocated. There was no familial history of congenital abnormality.

Open reduction of the right hip had been done elsewhere when the child was two years old. Treatment of the knee, however, was limited to a brace (Figs. 10-A and 10-B).

The child was examined by us on March 8, 1958, when she was twelve years of age; she walked with a left-sided limp using a knee brace. Hyperextension of the knee was painful. The femoral condyles were prominent in the popliteal space, and the hamstrings were anterior to the femoral condyles. The popliteal vessels were palpable in the intercondylar region. The tibia was externally rotated 35 degrees at the knee. The left limb was thirty-two and one-half inches long, and the right, thirty-three. Although the patella was not visible, it could be palpated in the suprapatellar area. Passive motions of the knees were as follows: extension was complete and flexion was 130 degrees in the right knee; in the left knee there were 20 degrees of hyperextension and 15 degrees of flexion. The left knee was very unstable; it would go into 30 degrees of valgus and 15 degrees of varus. Little anterior or posterior rocking could be elicited.

The quadriceps muscle was functioning, but it was difficult to evaluate its strength since the medial hamstrings coursed anterior to the femoral condyles and actually functioned as extensors of the knee. Motions of the right hip were limited, and roentgenograms showed residual evidence of an old aseptic necrosis of the femoral head associated with the congenital dislocation.

Roentgenograms of the left knee showed the left tibia to be displaced anterior to the femur. The tibial epiphysis was wedge-shaped and the femoral epiphysis was narrow anteri-

FIG. 10-A FIG. 10-B

G.S., a girl, twelve years old. Untreated congenital dislocation of the left knee. Note that the left patella is not visible in either the front or side view.

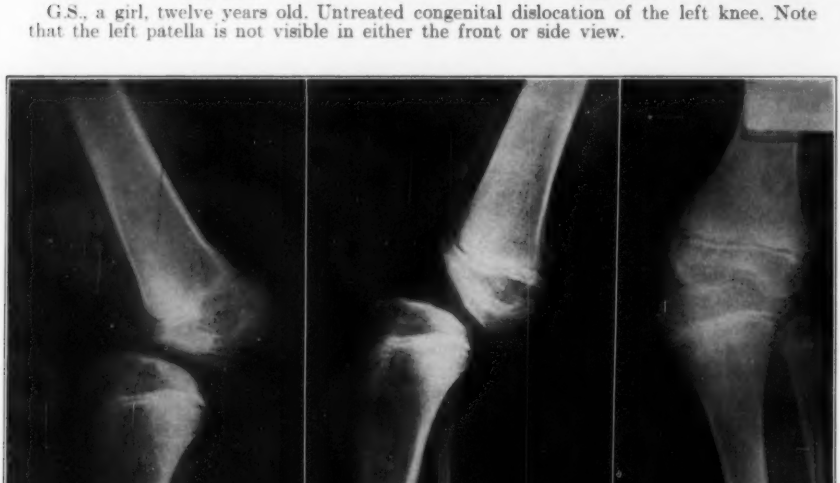

FIG. 10-C

Lateral roentgenograms show the range of flexion and extension. The anteroposterior view shows the lateral subluxation. Note deformity of both femoral and tibial epiphyses.

orly and wide posteriorly. The small and demineralized patella was in the suprapatellar area (Fig. 10-C).

The left knee was explored through a transverse incision, which was carried down through the patellar tendon. The anterior thirds of the semilunar cartilages were atrophic, but the posterior portions appeared to be normal. Although the anterior quarter of the articular surface of the tibia was covered by fibrous tissue, the posterior three-quarters was actually covered by good articular cartilage. The intercondylar groove was deep. The anterior cruciate ligament was very large and well developed, but no posterior cruciate ligament could be found. The patella had no relation to the knee joint, being located proximal to a small supracondylar pouch and embedded in fibrous tissue. Nonetheless, when traction was placed on it with a clamp it seemed to have an excursion of one inch.

After reduction of the dislocation with the knee placed in 30 degrees of flexion, there was a separation of approximately two inches between the cut ends of the patellar tendon. The knee was very unstable when reduced because of the incongruous articular surfaces of

the tibia and femur. Accordingly, the knee was fused, using the compression technique, in 15 degrees of flexion. As a result of this procedure the child's gait has improved and she is much more stable when standing and walking.

M. H., a woman, sixty-seven years of age, was admitted to the hospital for reasons other than her knees. She had no complaints regarding her knees and had worked as a hotel clerk most of her life. Although she had been seen by many doctors, she had never received any treatment for her knee deformities. The family history was negative.

FIG. 11-A

Figs. 11-A and 11-B: M.H., a woman, sixty-seven years old. Despite untreated bilateral congenital dislocation of the knees, this patient is still able to walk reasonably well and is earning her living at this time.

FIG. 11-B

On examination there was an obvious anterior dislocation of both knees. Although her gait was slightly unsteady, she could walk quite well. The femoral condyles were prominent posteriorly, and the popliteal vessels were palpable in the intercondylar groove. The patellae were small but palpable, and the quadriceps muscles were functioning. The hamstrings passed anterior to the femoral condyles and served as extensors of the knee. When they contracted they produced some degree of lateral stability. The gastrocnemius muscles appeared to arise from the femoral condyles and seemed to be the main knee flexors. The tibiae were externally rotated 20 degrees in relation to the femora. Active knee motion on the right was from 175 to 130 degrees; on the left, from 175 to 148 degrees. Both knees could be extended passively an additional 10 degrees. Even in full extension both knees were unstable, with 25 degrees of lateral motion. Joint motions were painless.

TABLE I

Patient	Sex	Age at Admission	Diagnosis	Treatment of Knees	Result at Follow-up
D.F.	M	2½ yrs.	CDK*, bilateral; and CDH**, right	Open reduction, knees	Died from unrelated cause one year after surgery; knees and hips were reduced
L.L.C.	F	6 mos.	CDK, bilateral	Traction, bilateral, 6 wks.; manipulation and casts: left knee, 5 mos.; right knee, 8 mos.	Excellent stability and motion at 2 yrs.; discharged
J.N.T.	F	21 mos.	CDK, bilateral	Traction and casts, bilateral; open reduction, right knee	No limp at age 10; active motion: right knee, 165 to 75 degrees; left knee, 180 to 90 degrees
C.J.Y.	F	4 mos.	CDK, left	Manipulation and casts, 6 mos.	Normal knee at age 9
M.L.W.	F	1 day	CDK, right	Manipulation and casts, 5½ mos.	Normal knee at age 5
R.P.	F	1 mo.	CDK and CDH, both bilateral	Traction, 2½ mos.; then manipulation and casts	Moved away, but written report states that "knees flex to 90 degrees"
L.C.G.	M	2 days	CDK, right	Manipulation and casts, 2 mos.	At age 2, normal right knee; hyperextends slightly more than left knee
R.H.	F	4 mos.	CDK, right; CDH, bilateral	Manipulation and casts; open reduction, hips	At age 3, knee reduced, full motion; hips reduced, gait normal
D.S.	M	1 wk.	CDK and CDH, both bilateral; calcaneal valgus feet	Open reduction, knees and hips	Knees reduced at age 2½; hips reduced; walks (braces worn for feet)
G.S.	F	12 yrs.	CDK, left; CDH, right	Arthrodesis, left knee; open reduction of hip, age 2	Good stability, gait improved
C.P.	F	5 mos.	CDK, bilateral; CDH, bilateral; bilateral dislocated elbow, club-foot, and club-hand	Manipulation, knees; further treatment not carried out	Knees not reducible on manipulation
M.H.	F	67 yrs.	CDK, bilateral	None	Gait fair

* CDK: Congenital dislocation of the knee.
** CDH: Congenital dislocation of the hip.

C. P., a white girl, was born on July 24, 1958. Delivery was probably not by breech presentation. There was no family history of any congenital malformations.

When the child was examined at Stanford University Hospitals on January 30, 1959, she was found to have bilateral congenital dislocations of the elbows, hips, and knees; a congenital deformity of the mandible; bilateral club-foot; and bilateral club-hand. The knees could be hyperextended 80 degrees and passively flexed to a position of 30 degrees of hyperextension. The dislocations of the knees and the other dislocations could not be reduced by manipulation (Figs. 8-A and 8-B). Further treatment was not carried out by us.

SUMMARY

Twelve patients with congenital dislocation of the knee (nineteen knees) were studied.

Genetic factors appear to predominate in the etiology of the condition, although the effects of environment on the fetus cannot be entirely discounted. The condition is frequently associated with other congenital anomalies and has a higher incidence in females than in males. It is relatively rare compared with congenital dislocation of the hip, but in many ways these two anomalies are similar.

Congenital dislocation of the knee is, in essence, a dislocation of the proximal part of the tibia anterior to the articular surface of the femur. With the less severe deformities, excellent results are obtained by early treatment with conservative measures. The technique of open reduction, when indicated, is varied according to the deformity. In one knee with a severe long-standing deformity arthrodesis was necessary.

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Clinical Experiences with the S.A.C.H. Foot Prosthesis

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Artificial limbs have been considerably improved since the time of the earliest peg leg which consisted of two components, a socket for the stump and a peg to support the amputee's weight. Although utilitarian, the transmission of the complete shock of the heel strike to the stump jarred the amputee with every step, and caused frequent stump problems. In addition, an amputee with a peg leg could not in any way simulate a normal gait pattern.

Since World War II there has been considerable research in prostheses for both upper-extremity and lower-extremity amputees, directed toward improvement of successive individual components in order to improve the prosthesis as a whole. One of the most successful phases of this research has been the evolution of the Solid Ankle Cushion Heel prosthetic foot, abbreviated as S.A.C.H.*

Modern lower-extremity prostheses consist of seven to eight major components, specifically prescribed for the needs of the individual amputee in the same manner as a medical prescription. The order for an artificial limb should indicate not only the kind of socket, but also the necessity of a pelvic strap, belt, or quadriceps-extension aid, the type of knee joint (which may include an auxiliary mechanical or hydraulic mechanism), wood, metal, or plastic shank, and the specific type of ankle-and-foot assembly desired.

Heretofore, a single-axis ankle assembly, the simplest type of articulating ankle joint, has been commonly used as the conventional component because of economy of installation and maintenance. This component does not provide any lateral motion or inversion and eversion of the foot, nor does it absorb any of the torque produced in walking, which is thus transmitted directly to the socket and thence to the stump. The single-axis type utilizes a firm-rubber bumper in front to limit dorsal flexion and a softer-rubber bumper posteriorly to restrict plantar flexion. These bumpers must be replaced as they become worn to ensure smooth performance of the prosthesis, but frequently they do not receive prompt attention by the amputee, resulting in a faulty gait during the period of excessive wear.

Another type of prosthetic ankle assembly is the double-axis ankle, which permits plantar and dorsal flexion of the ankle and inversion and eversion of the foot by utilizing two additional lateral bumpers but does not compensate for the torque caused by walking. The transverse-rotation ankle is still another type, which utilizes cables or cords running through a rubber block fastened to the shank above and to the foot below. This arrangement permits plantar flexion and dorsal flexion, inversion and eversion, and transverse rotation with some absorption of torque. However, both of these assemblies require frequent repairs, and proper maintenance is difficult and time-consuming. These deficiencies have retarded the general acceptance of these devices, except under special circumstances in which unusual job requirements have necessitated walking over rough ground and a limb shop has been available for ready repairs. Some amputees have requested this particular device and have been supplied with it.

* New York University, College of Engineering, Research Division, Prosthetics and Sensory Aid Service, Veterans Administration Report Number 115.23, May 1957: Evaluation of the Solid Ankle Cushion Heel Foot.

The prosthetic foot is of great importance in determining how the forces of weight-bearing are transmitted upward to the socket and stump. It is a major factor in facilitating walking and making possible an approximately normal gait. The foot must be durable and relatively simple in construction to obviate the need for frequent repairs or replacements; it must be comfortable with an acceptable appearance; it must be light in weight, yet capable of absorbing the shock of heel strike; and it must permit the use of conventional shoes. Many types of prosthetic feet have been designed and are in general use, including the most commonly used wooden foot, with or without a felt toe, an all-rubber foot, and a modified wooden foot with a compressible heel and toe. In the wooden foot the location of the toe break, corresponding to the metatarsophalangeal joints of the normal foot, significantly influences the amount of toeing-in or toeing-out associated with gait; this must be carefully adjusted for each individual amputee.

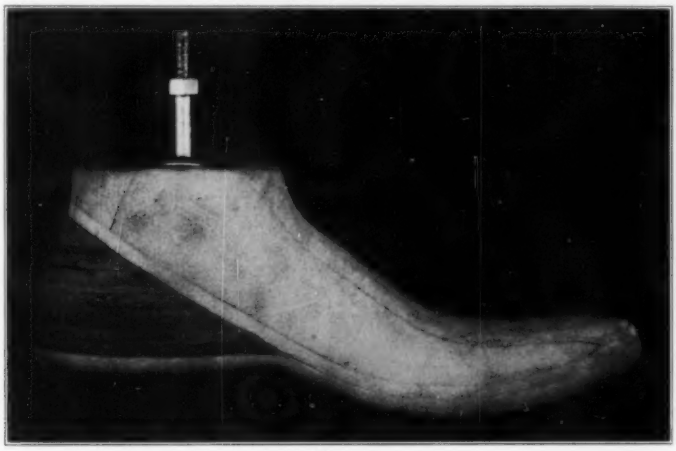

FIG. 1

The S.A.C.H. foot for an adult, shaped for the final fitting. Note the elevation of the heel to allow for the usual heel height of eleven-sixteenths of an inch in men's shoes.

The S.A.C.H. prosthetic foot was developed at the University of California at Berkeley in 1955, based on a Canadian prototype for a Syme prosthesis. In it the ankle and foot are combined into one component, consisting of a rigid wooden keel with a compressible heel firmly attached to the shank of the leg so as to eliminate the constant loosening and resultant torsion which occur with the U-bolt assembly by which the conventional wooden foot is attached to the ankle and shank. This device has been critically evaluated and modified as a result of intense scientific studies by the Prosthetic Devices Study Section of New York University College of Engineering, Research Division, in conjunction with the Engineering Division of the University of California, Berkeley, both sponsored by the Veterans Administration through its prosthetics center in New York City. These investigations have included studies of the compressibility of both assembled and unassembled heel wedges; trials of experimental models under static conditions and under the dynamic compression of actual gait; stability tests with the amputee walking and standing on inclined planes and beams or balancing on a single leg; and gait analyses during walking on level ground. Various methods of study, including precise roentgenographic techniques, have been developed during these investigations which have established the specifications and basic standards for the manufacture of this device. The S.A.C.H. foot is now manufactured on a commercial basis and is in general use throughout the United States and Canada.

STRUCTURAL CHARACTERISTICS

The foot is composed of a keel of hard wood shaped at the ball of the foot to provide a rocker action and of a cushioned heel of multiple laminations of neoprene and sponge rubber. The keel is covered on its plantar surface by belting which is attached to the keel with two wood screws and serves to prevent the keel from penetrating through the underlying rubber base. A neoprene toe extends forward from the anterior margin of the keel which ends just proximal to the ball of the normal foot.

The installation and adjustment of the S.A.C.H. foot directly influence the gait characteristics of the amputee who wears the completed prosthesis. The S.A.C.H. foot is attached to the wooden shank by means of a three-eighths-of-an-inch steel carriage bolt, the head of which is embedded into the hard wooden keel. A solid section of wood of one and one-half to two inches in length is required at the distal end of the leg shank to receive this bolt; if the leg shank is

FIG. 2

The S.A.C.H. foot for women, shown in the rough form in which it is supplied to the prosthetist for final shaping and fitting. Note the increased height of the heel and the increased obliquity of the keel for the higher heels of women's shoes.

made of some other material, a similar wooden section must be added to its lower extremity to permit the attachment of the S.A.C.H. foot. Because of the compressibility of the S.A.C.H. foot under load, the shank must be made one-fourth of an inch longer to compensate for this for the average amputee. However, if an amputee weighs less than 140 pounds, or if an extremely hard heel cushion of minimum compressibility is used, the additional length of the shank required may be less than one-fourth of an inch. The attachment of the foot to the shank, after adjustments have been completed, is re-inforced by glued dowel joints between the keel and wooden section in the end of the shank.

The foot must be fitted to the shoe by contouring it so that the shoe fits snugly under the malleoli and tightly across the vamp and about the bottom of the heel, with a relatively loose fit over the toes and around the medial, lateral, and the posterior aspects of the heel where motion occurs during walking. Approximately one-eighth of an inch of clearance must be allowed around the brim of the shoe counter to permit lateral bulging of the rubber heel during weight-bearing. The shoe must also have a looser fit about the toe-break area of the front of the S.A.C.H. foot than is necessary with a wooden foot because the flexible material expands dorsally as the toe bends. Insufficient clearance restricts toe motion and damages the shoe. Similarly, one-eighth of an inch of clearance must be provided between the plantar arch of the foot and the inner sole of the shoe to compensate for the expansion of the heel in this region during weight-bearing.

The heel of the foot is shaped so that the point of the heel is displaced one-fourth of an inch lateral to the mid-line. Unless this is done, the body weight will be transferred through the lateral side of the heel cushion at the time of heel contact. During proper toeing-out gait the foot rotates outward about the axis of the leg at heel strike, with the result that the front part of the foot moves laterally while the point of the heel moves medially. By placing the point of the heel one-fourth of an inch lateral to the mid-line, the body weight is borne through the geometric center of the heel after toeing-out has occurred.

The cushioned heel must be suited to the individual requirements of the amputee. The S.A.C.H. foot is manufactured with firm, medium, and soft heels. These different heels are used according to the type of amputation, body weight of the amputee, and functional considerations based on engineering and medical evaluation studies. The prosthetist can easily modify the heel by removing heel wedges and replacing them with wedges which are more or less compressible according to

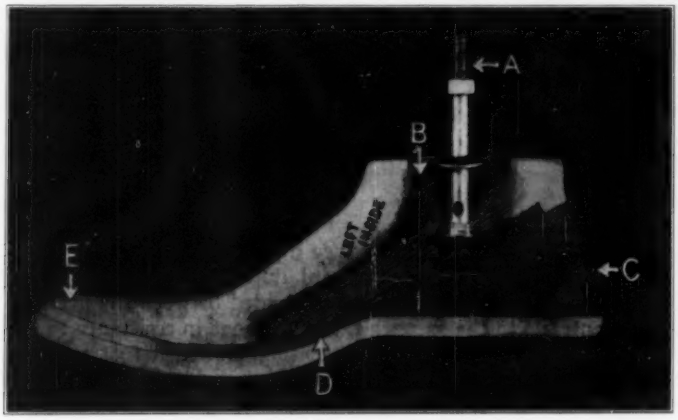

FIG. 3

A sagittal section of the S.A.C.H. foot for a man. *A* = the carriage bolt, three-eighths of an inch in diameter, with the head embedded in the keel; *B* = wooden keel; *C* = laminated cushioned rubber heel; *D* = belting between neoprene outer cover and wooden keel; and *E* = neoprene toe.

the requirements of the amputee. The S.A.C.H. foot is presently manufactured with a heel elevation of eleven-sixteenths of an inch—that is, the bottom of the heel is eleven-sixteenths of an inch above the level of the ball of the foot—to conform with the height of standard heels on men's shoes. The heel elevation may be varied by increasing or decreasing the thickness of the heel cushion as required by the amount of heel-cushion compression which occurs when the amputee stands on the prosthesis. Limited plantar flexion of the foot in walking and decreased knee stability in both walking and standing result from excessive heel-cushion compression when the amputee is standing with the top of the prosthetic foot parallel with the floor and may require removal of crepe-sole material from the bottom of the heel of the S.A.C.H. foot to increase the elevation of the heel in the stance phase and thereby facilitate rollover to the toe. On the other hand, if there is excessive knee stability this will cause the amputee to feel as if he is walking over a hill, and a thicker heel cushion may be required. This can be accomplished by cementing firm flexible material to the bottom of the heel area of the prosthetic foot. The need for changes in heel-cushion thickness is indicated by trial-and-error observations in both the standing and walking positions.

At present, S.A.C.H. feet are provided in five shoe-size ranges—4 to 6, 6 to 8, 8 to 10, 10 to 12, and 12 to 14—with the length of the keel from toe break to ankle increasing by one-fourth of an inch for each size range. In addition, special sizes and shapes of feet are now available for women and children.

For a Syme prosthesis, the S.A.C.H. foot has been modified. A lower heel of firmer consistence is attached to a wider and larger keel, and the bolt is reversed to avoid protrusion of its threaded end and nut into the socket.

The foot is fixed in position only after final adjustment of the toe-out position and after walking trials have been carried out with the keel in various positions of inversion-eversion in relation to the ankle center. In some instances it is necessary to initially place the keel forward or backward to provide the best gait for an individual amputee or to prevent excessive dorsiflexion of the toe with heel strike. Finally, the foot is fastened to the shank with predetermined allowances (usually one-quarter-inch addition to the length of the shank to compensate for compression of the S.A.C.H. foot under load) to provide the same length of shank as with a conventional wooden foot by securely tightening the nut and lock washer of the three-eighths-of-an-inch carriage bolt, and securing the keel to the lower extremity of the shank with dowels and glue.

The S.A.C.H. foot can be used for all types of lower-extremity prostheses except for those employed for partial amputations of the foot. When used with a Syme prosthesis, the S.A.C.H. foot must be modified in shape, as already indicated.

FUNCTIONAL CHARACTERISTICS

The S.A.C.H. foot provides shock absorption and ankle function closely simulating that of the normal ankle without a movable ankle joint.

Plantar flexion at the ankle is simulated by compression of the cushion heel. This compression absorbs the shock of impact at heel strike, provides very smooth foot function of almost normal appearance during the initial stance phase, and permits gradual transfer of weight forward during the mid-stance or rollover phase, as the distribution of body weight is divided between the heel and ball of the foot. This contrasts to the somewhat jerky change in resistance to this weight transfer which is characteristic of a conventional wooden foot with an articulated ankle joint and a soft plantar-flexion bumper posteriorly and a firm dorsiflexion stop in front.

Heel contact of the average amputee causes about three-eighths of an inch of compression of the heel cushion, but this varies with body weight, type of gait, and so forth. The shape of the structural keel under the ball of the foot provides a smooth rocker action and thereby requires less energy for the push-off, especially when one walks up an incline, because the distance from the ankle center to the toe break is shorter than in most conventional feet.

RESULTS

The S.A.C.H. foot has been prescribed for 123 amputees through the Orthopaedic and Prosthetic Appliance Clinic of the Veterans Benefit Office of Washington, D.C.

From analysis of Table I it is noted that there were only three S.A.C.H. feet replaced out of the total of 123, or 2.4 per cent complete failures. In addition, there were three other amputees who found no significant differences between the S.A.C.H. foot and a conventional foot, making a total of 5 per cent who did not enthusiastically approve of substitution of the S.A.C.H. foot for their previous wooden foot. In addition, the prosthetists in our clinic team report that among the many hundreds of civilian amputees seen by them outside our clinic, to whom S.A.C.H. feet have been issued, they know of only two who have reverted to their previous type of foot. This confirms the impression of our clinic members that this prosthetic modification has received almost universal acceptance; the rare rejections were usually by amputees with established personality problems.

Of the 120 S.A.C.H. feet in constant use which we have followed, we have had to replace only four with new feet. One was replaced within a few months because of a defect in manufacture; another required replacement because it was

TABLE I

DATA ON DISTRIBUTION OF S.A.C.H. FEET TO 123 AMPUTEES

Type of Prosthesis	No. of S.A.C.H. Feet Issued	No. of S.A.C.H. Feet Unsatisfactory	No. of S.A.C.H. Feet Repaired	No. of S.A.C.H. Feet Replaced with Conventional Feet	No. of Amputees Satisfied	No. of Amputees Noticing No Difference
Canadian-hip-disarticulation prosthesis	3	0	0	0	2	1
Above-the-knee prosthesis (conventional and suction socket)	46	0	2	0	45	1
Below-the-knee prosthesis (slip socket, conventional, all types) unilateral	68	1	10	1	67	1
bilateral (3)	6	2	2	2	2	0
Syme's type prosthesis	3	0	1	0	3	0

worn out by the strong abrasive action of coal dust and sand resulting from four months of constant use in coal mining; a third was replaced after fifteen months of very strenuous use by an active automobile mechanic; and the fourth was replaced after eighteen months of use by a very active below-the-knee amputee.

The repair and maintenance of S.A.C.H. feet have been minor problems in contrast to the frequent repairs required by the conventional wooden foot, such as replacement of rubber ankle bumpers, tightening or replacement of stud bolts, repair of hinges at the toe break, or even total replacement after immersion in water. With the S.A.C.H. feet most repair jobs have consisted of the cementing of minor separations of the rubber laminations in the cushioned heel; the faulty application or removal of the shoe without a shoe horn results in tearing of the laminated-rubber heel from the posterior margin of the foot.

ADVANTAGES

The two principal advantages of the S.A.C.H. foot noted by amputees of all types were the shock absorption at heel strike, with resultant minimum jarring and irritation of the amputation stump, and the reduced amount of maintenance and repairs as compared with their previous wooden feet.

The following additional advantages were noted by a significant number of lower-extremity amputees of all types: (1) increased stability on rough or uneven terrain as a result of the lateral motion permitted by the flexible heel; (2) a springier step from the cushioned heel strike; (3) less fatigue with walking; (4) less irritation of the stump; (5) the fact that the foot feels more like a natural foot; (6) there is no tendency for the sock to draw up at the heel, and there is less tearing of socks from catching in the ankle joint or in the toe break, as in a wooden foot; (7) no oiling of joints is required, as there are no joints in the S.A.C.H. foot; (8) there is less noise with the S.A.C.H. foot than with a wooden foot, especially after prolonged use which often causes squeaks in the conventional wooden foot; (9) there is a more pleasing cosmetic appearance of the foot, especially noted by women and children amputees because of the elimination of the shank-to-foot fairing of articulated prosthetic feet; (10) reduced maintenance with elimination of the need for periodic replacements of worn-out rubber bumpers and for tightening of a loose U-bolt at the ankle joint so that, as a result, the increased rotation stress associated with defective rubber bumpers or a loose U-bolt is avoided; (11) there is minimum deterioration of the S.A.C.H.

foot, in contrast to the wooden foot, from dampness and wetting, which is important in children amputees and amputees with outdoor occupations or avocations, particularly those who work regularly in damp areas; and (12) there is no loosening of the foot at the U-bolt with constant use, as usually occurs with an articulated wooden foot, with the result that the foot feels tighter.

DISADVANTAGES

The restrictions and disadvantages of the S.A.C.H. foot are few and, in most instances, of relatively minor importance. Its major disadvantage is related to instability which results from the compressible heel. This impairs balance during standing and during the stance phase of gait, primarily in bilateral above-the-knee amputees, most of whom have been unable to use this type of foot; for this reason the S.A.C.H. foot is usually not ordered for these amputees.

The following disadvantages or difficulties have also been noted by amputees in our clinic: (1) instability when walking up an incline due to the rocker action caused by the compression of the rubber heel, noticed especially by bilateral above-the-knee amputees and to a lesser degree by some of the bilateral below-the-knee amputees; (2) difficulty in putting on socks or stockings directly over the S.A.C.H. foot, which is, however, easily overcome by using a thin silk or nylon sock as a permanent base or cover for the S.A.C.H. foot; (3) difficulty in depressing the accelerator of an automobile, resulting in fatigue after driving for long distances, which is due to the absence of an articulated ankle joint, thereby necessitating increased use of the muscles of the thigh or upper part of the leg; (4) curling up of the toe at heel strike, which was sometimes associated with an occupation necessitating excessive bending or stooping, but which, however, can be corrected by the proper alignment of the foot with the shank; (5) difficulty in climbing stairs was noted by those above-the-knee amputees who used the normal gait pattern of lifting one foot after the other, which, however, most above-the-knee amputees do not use; (6) insufficient break at the toe (reported by only one amputee); (7) limitation in the choice of shoe style, because, even though chukka boots and high-top shoes have been successfully used by some amputees, the stiff upper part tends to impair the compressibility of the heel cushion, causing lateral bulging of the shoe and diminution of the cushion effect, and, for women, pumps or other styles without an instep strap were at first considered unsuitable, but they can now be worn when close fitting of the shoe to the foot has been achieved; (8) inability to use canvas shoes because the thin and pliable heel counter permits excessive lateral and posterior bulging of the S.A.C.H. foot when it is compressed; (9) occasional separation of the laminations at the heel, which, however, can be easily repaired with rubber cement in most instances; and (10) difficulty in dancing because of the limited torque, but this objection also applies to the single-axis ankle of an articulated wooden foot.

In addition to the objections just listed, one amputee was dissatisfied with the soft heel, as he had become accustomed to the firm heel strike of his wooden foot. This soft feeling is noticed by all amputees but they usually become accustomed to it after a few days of using the S.A.C.H. foot. Occasional squeaking noises have been noticed with the S.A.C.H. foot, but they are almost always due to a defect in manufacture—usually, loose belting between the sole and heel. At first, most amputees have a feeling of pitching forward as they step forward and roll over on the S.A.C.H. foot, but this sensation usually disappears after three or four days of use.

INSPECTION OF S.A.C.H. FEET

Although the S.A.C.H. foot has proved to be very durable in our experience, nevertheless, we believe that periodic examination is desirable to detect early defects that can be corrected by minor repairs. The amputee should be encour-

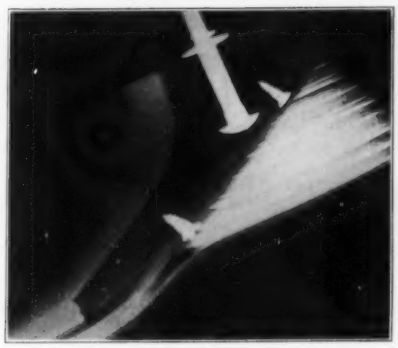

FIG. 4

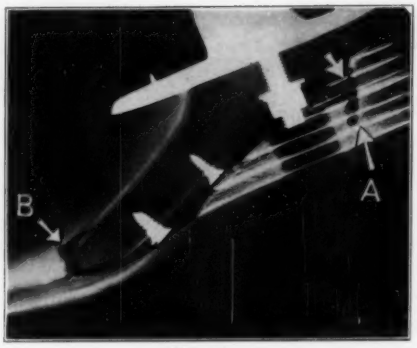

FIG. 5

Fig. 4: Lateral roentgenogram of the intact S.A.C.H. foot for comparison with a defective foot.

Fig. 5: Lateral roentgenogram of a damaged S.A.C.H. foot. *A* = separation of the rubber lamina posteriorly in the cushioned heel from improper insertion and withdrawal from the shoe without the use of a shoehorn; and *B* = detachment of belting around the forward screw, with resultant abnormal wear that causes squeaking with walking.

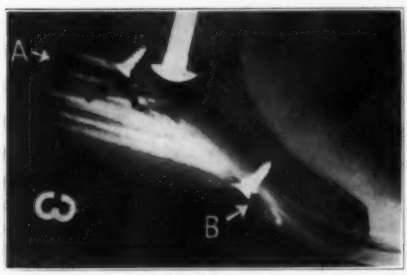

FIG. 6

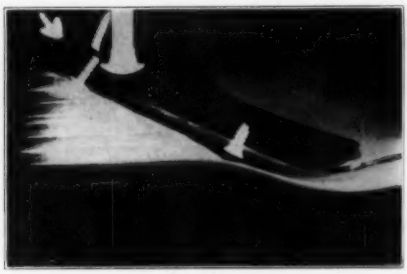

FIG. 7

Fig. 6: Lateral roentgenogram of a defective S.A.C.H. foot. *A* = vertical tear in the neoprene laminated cushioned heel; and *B* = abnormal motion at the forward tip of the keel, with crepitus between the keel and the neoprene cover, causing a squeaking noise at push-off in walking.

Fig. 7: Lateral roentgenogram of a noisy S.A.C.H. foot. Note the broken screw in the rear of the foot which is responsible for detachment of the belting from the keel and the resultant squeaking at heel contact and push-off.

aged to return for regular check-up examinations by the prosthetic clinics, or, if such clinics are not available, by the limb manufacturer. The examination usually consists in a critical inspection of the foot with the shoe and sock removed, in addition to gait analysis and observation of the foot during walking.

The detection of internal defects in the S.A.C.H. foot is usually a simple problem for the experienced prosthetist. For example, a noisy, clicking foot is usually because of a detachment or loosening of the belting beneath the keel, and excessive turning-up or curling of the neoprene toe is due to protrusion of the anterior end of the keel through the belting and rubber sole. In some cases, however, the prosthetist must dismantle the foot in order to discover internal defects, such as a broken screw attaching the belting to the keel, fracture of the tip of the wooden keel, excessive separation of the rubber from the anterior or posterior margins of the keel, or loosening or breakage of the carriage bolt embedded in the keel.

We have learned that lateral roentgenograms are sometimes quite helpful in establishing the diagnosis of an ailing S.A.C.H. foot. By comparison with a roentgenogram of an intact prosthetic foot, the flaw becomes quite obvious, permitting the prosthetist to make the required repairs without unnecessary dis-

mantling. Roentgenograms of typical defects discovered in our clinic are presented in Figures 5, 6, and 7.

CONCLUSIONS

The solid ankle cushion heel, or S.A.C.H., foot has proved to be a valuable component for lower-extremity prostheses; it can be used with all prostheses that require a full artificial foot.

There is significantly less irritation of the amputation stump with use of the S.A.C.H. foot, especially in below-the-knee amputees, because of the diminished torsion upon the stump and less jarring from heel impact.

The degree of comfort for the amputee using an artificial lower limb with a S.A.C.H. foot is increased as a result of the cushioned heel and smooth rocker action.

The continued use of an improperly aligned prosthesis often occurs with a conventional wooden foot which has become loose at the articulated ankle joint. Tightening and repairs to the wooden foot and ankle joint are often postponed or deferred by the amputee until stump irritation finally forces him to seek repairs; the skin ulceration or abrasion may then result in unnecessary deprivation of the use of the prosthesis until the stump has healed. Such problems are definitely diminished with the use of a S.A.C.H. foot.

The S.A.C.H. foot represents a significant advance in prosthetic research. It is now being prescribed extensively for all lower-extremity amputees, and appears likely to replace the wooden foot and articulated ankle joint as the conventional component for all lower-extremity prostheses.

Deformity Following Supracondylar Fractures of the Humerus*†

BY LYMAN SMITH, M.D., ELGIN, ILLINOIS

Change in the carrying angle of the elbow is the most common complication with which we have to deal in the treatment of supracondylar fractures of the humerus. It is not only the most common but it is also the most neglected complication.

It is neglected because of fear of the dreaded but very rare complication of ischemic contracture; because of nerve lesions, which have such a good prognosis; and because the functional results after adequate conventional forms of treatment are routinely satisfactory. Yet various series have been published in which the incidence of carrying-angle change after supracondylar fractures of the humerus has been as high as 57 per cent, and the average in most groups has been approximately 30 per cent [2,7,13,17,19,20].

Some surgeons seem to have the attitude that carrying-angle changes are a necessary evil. The extreme of this point of view was expressed as follows: "A gunstock deformity with a strong elbow and a full range of motion is not counted a poor result" [11]. Attenborough showed four cases of irreducible supracondylar fractures of the humerus which had been immobilized in plaster with little or no apposition of the fragments. The functional end result in all four patients was satisfactory, but unfortunately three of the four were left with cubitus varus deformity. When Watson-Jones stated, "The prognosis of supracondylar fractures is excellent," he must have been speaking of restoration of function, not of form. The functional end result is uniformly adequate with practically all acceptable methods of treatment, but the incidence of carrying-angle change is unnecessarily high.

By definition, even 1 degree of carrying-angle change at the elbow may be termed a deformity. Obviously, changes in the carrying angle which are so minor as to be apparent only to examination by an experienced surgeon are not of critical importance. Any change, however, which is of sufficient degree to be noted by the parents and rationalized by them with some such statement as "the arm looks funny, but Johnny can do anything with it," is excessive and should be avoided.

In 1940, I aided in an end-result study of fifty supracondylar fractures of the humerus at the Boston City Hospital [2]. Of these fifty fractures, twenty-three showed definite changes in the carrying angle, and fifteen were severe enough to be called gunstock deformities, although all had satisfactory function. An analysis was made of the postreduction roentgenograms of these elbows in an attempt to correlate adequacy of the reduction with the end result. It was concluded that loss of the carrying angle was caused by persistent medial displacement and internal rotation of the distal fragment around the long axis of the arm, which was not a new view and was concurred in, many times, in other publications [3,10,12,13,16,17,18,20].

In 1954, however, a case was examined in which the findings did not conform to this concept. A young boy had sustained a completely displaced supracondylar fracture of the humerus a few years previously and had been left with a severe varus deformity. Examination of the posterior aspect of this elbow in

* Read at the Annual Meeting of the American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1959.

† This study was supported by the Committee for the Advancement of Research, Sherman Hospital, Elgin, Illinois.

FIG. 1-A

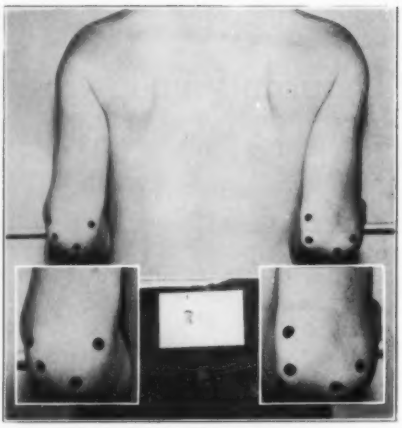

FIG. 1-B

Fig. 1-A: R. M., age nine. Change in the carrying angle cannot be detected if the flexed elbows are examined from in front.

Fig. 1-B: Change in the carrying angle is quite apparent, however, if the flexed elbows are examined posteriorly. On the right, the bone prominences (marked with black dots) can be seen to have tilted medially.

FIG. 1-C

FIG. 1-D

Fig. 1-C: With the arms extended, a 25-degree varus deformity of the right arm can be seen two years after a supracondylar fracture. There is no limitation of motion. Note that the normal carrying angle of the left arm is 0 degree.

Fig. 1-D: When the varus elbow is acutely flexed, the hand points laterally to the shoulder joint. This view also demonstrates the medial tilt of the bone prominences.

the flexed position was surprising (Fig. 1-B). If the deformity was secondary to an internal rotation of the distal fragment as previously postulated, the olecranon process of the ulna should have been carried laterally as the anterior surface of the distal fragment turned medially. To the contrary, the olecranon, along with the other bone prominences of the elbow, was found to be tilted far medially in relation to the long axis of the shaft of the humerus.

It was this observation which initiated this study which has included 106

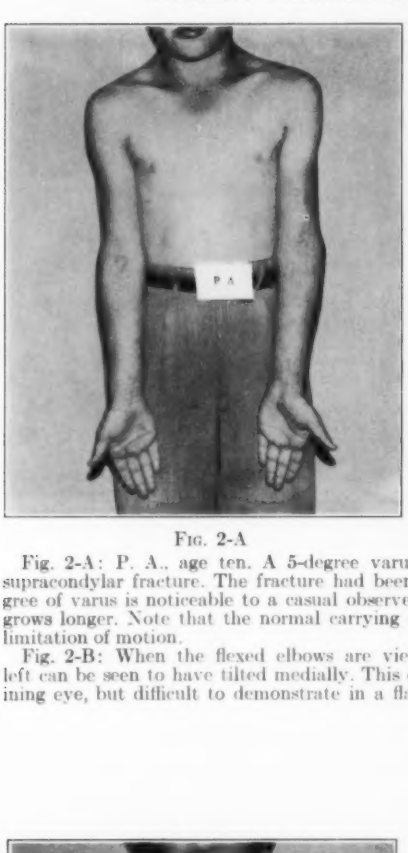

FIG. 2-A

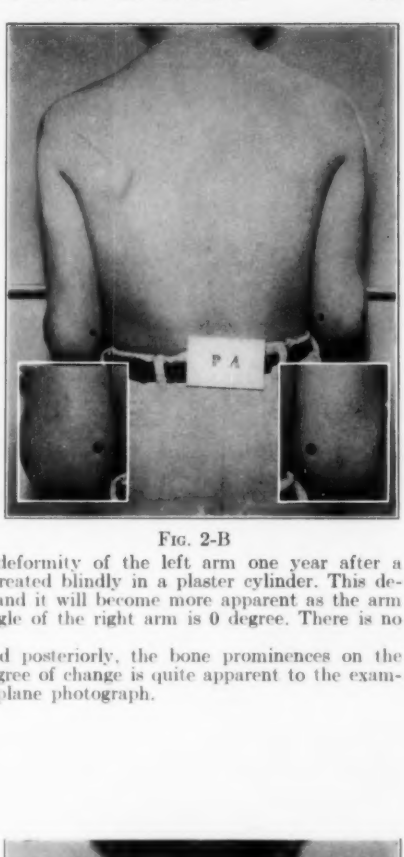

FIG. 2-B

Fig. 2-A: P. A., age ten. A 5-degree varus deformity of the left arm one year after a supracondylar fracture. The fracture had been treated blindly in a plaster cylinder. This degree of varus is noticeable to a casual observer and it will become more apparent as the arm grows longer. Note that the normal carrying angle of the right arm is 0 degree. There is no limitation of motion.

Fig. 2-B: When the flexed elbows are viewed posteriorly, the bone prominences on the left can be seen to have tilted medially. This degree of change is quite apparent to the examining eye, but difficult to demonstrate in a flat-plane photograph.

FIG. 3-A

FIG. 3-B

Fig. 3-A: D. J., age six. A 2-degree varus deformity of the left arm three years after supracondylar fracture. The fracture had been treated blindly by immobilization in a spica cast. The normal carrying angle on the right is 8 degrees. There is no limitation of motion.

Fig. 3-B: When the flexed elbows are examined posteriorly, it can be seen that the contours are not symmetrical. There is medial tilt of the bone prominences on the left.

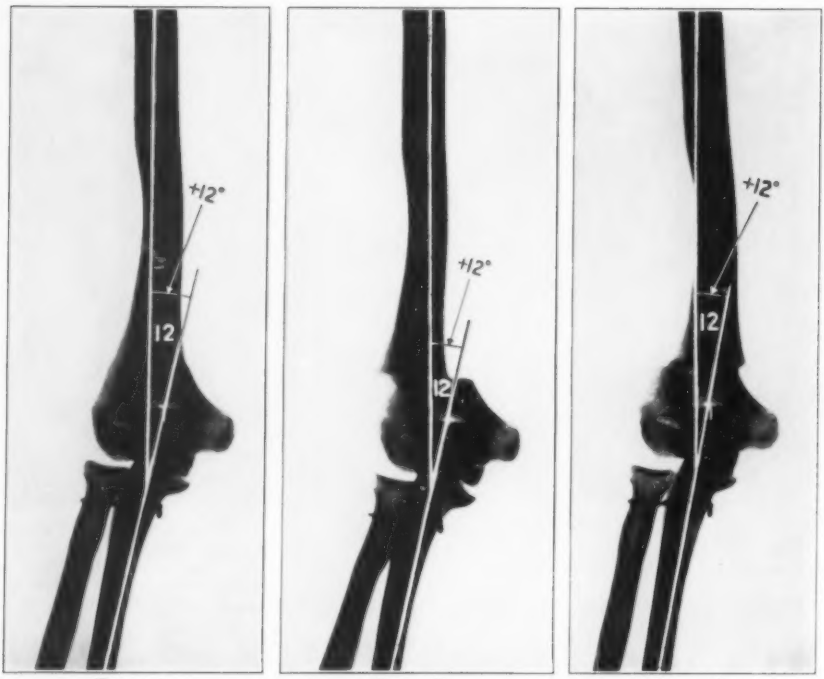

FIG. 4-A FIG. 4-B FIG. 4-C

Figs. 4-A through 4-F: Effect on the carrying angle of various displacements of the fragments.
Fig. 4-A: The carrying angle of this elbow was 12 degrees of valgus.
Fig. 4-B: The distal fragment was displaced medially, and the carrying angle did not change from its 12 degrees.
Fig. 4-C: The carrying angle did not change with lateral displacement of the distal fragment.

children with healed supracondylar fractures of the elbow who have been examined and roentgenograms of the elbows of fifty-two other children. The available literature in English on the subject has been reviewed. The findings in these studies and in various experiments have led to a so-called visual method of treatment which has been successful in preventing carrying-angle change in twelve cases. Only the displaced extension type of supracondylar fractures are considered, since undisplaced or incomplete fractures and the uncommon flexion type present no problem in regard to the residual deformity under consideration here.

THE CARRYING ANGLE OF THE ELBOW

The carrying angle is most apparent and best visualized when the shoulder is externally rotated, the elbow is completely extended, and the forearm is supinated. Pronation of the forearm tends to conceal the carrying angle, as does flexion of the elbow. As the elbow is flexed from complete extension, the carrying angle becomes less evident until complete flexion is reached, at which time the forearm covers the arm and there is no apparent deviation. However, if the flexed elbow is examined posteriorly and compared with the opposite elbow, even a slight change in the carrying angle is quite apparent (Figs. 2-B and 3-B). If there is any change, the three or four posterior bone prominences can be seen to tilt together either medially or laterally from the long axis of the humerus. It is not possible by measurements to tell the exact number of degrees that the carrying angle has been altered, but the fact that it has increased or decreased is obvious. Usually, only three prominences are evident—the medial epicondyle, the olecranon, and the lateral epicondyle—and they form a fairly symmetrical

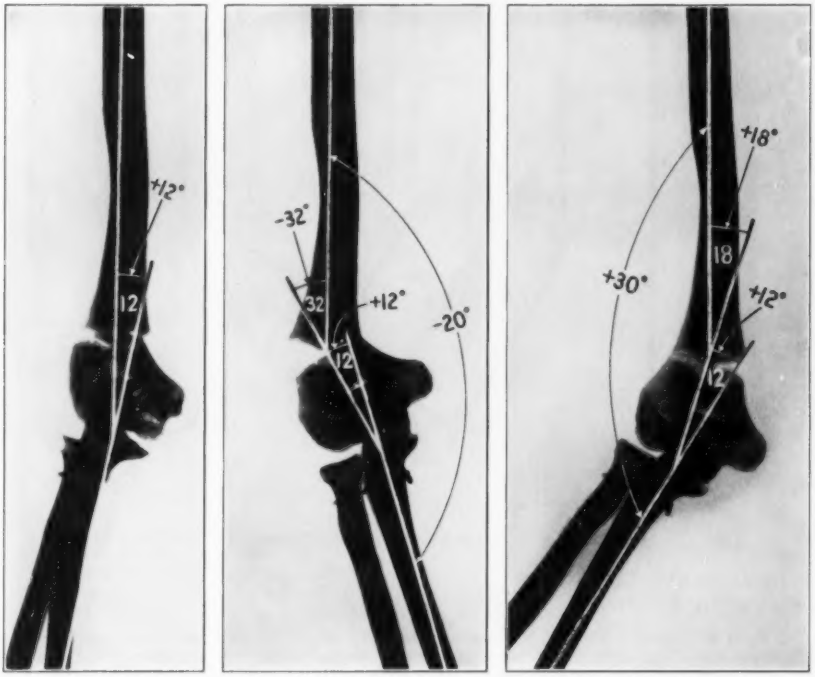

FIG. 4-D FIG. 4-E FIG. 4-F

Fig. 4-D: The distal fragment was rotated internally 15 degrees, and the carrying angle did not change.

Fig. 4-E: The distal fragment was tilted medially 32 degrees, and the carrying angle changed to 20 degrees of varus.

Fig. 4-F: The distal fragment was tilted laterally 18 degrees, and the carrying angle increased to 30 degrees of valgus.

equilateral triangle. However, in many children, the capitellum becomes quite prominent at 90 degrees of flexion and destroys the symmetry of the lateral segment of the triangle (Fig. 1-B).

The angle formed by the long axes of the humerus and ulna is subject to considerable individual variation, as was emphasized by Aebi in a detailed study of its relation to age and sex. His measurements of 100 subjects showed values considerably less than those usually quoted [3,8,14,23]. The values in men averaged 6.5 degrees, with a range from 0 to 14 degrees; in women, the average was 13 degrees, with a range from 4 to 20 degrees. The differences in the carrying angles in the two sexes did not appear until puberty.

In a study of 150 normal children comprising eighty girls and seventy boys, aged three to eleven years (the age when supracondylar fractures are most common), I found the average carrying angle to be 6.1 degrees in the girls, with a range of 0 to 12 degrees, and 5.4 degrees in boys, with a range of 0 to 11 degrees. These angles were determined by measuring the angle formed by lines joining the mid-point of the wrist and the mid-point of the humeral head, as located by palpation, with the mid-point of the antecubital space with the elbow fully extended and the forearm in supination. It is of particular interest that 9 per cent of these normal children had a cubitus rectus or no carrying angle, and 48 per cent had a carrying angle of 5 degrees or less. If a child with such a slight carrying angle sustains a supracondylar fracture, and the fragments heal with disalignment of only a few degrees, an obvious varus may be the result (Fig.

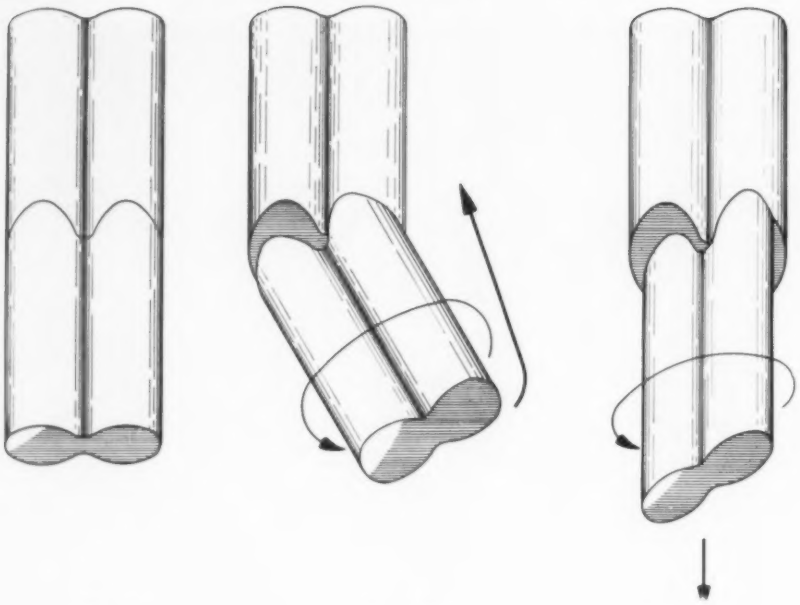

FIG. 5-A FIG. 5-B FIG. 5-C

Fig. 5-A: Mechanical drawing to illustrate the influence of rotation on the alignment of an oblique fracture. The plane of the fracture line is at 45 degrees to the long axis of the humerus. The central longitudinal constriction of the cylinder simulates the thin portion in the distal part of the humerus at the level of the olecranon and coronoid fossae.

Fig. 5-B: With 60 degrees of rotation of the distal fragment and compression forces applied, 30 degrees of angulation must occur (see text).

Fig. 5-C: With traction applied, angulation is prevented.

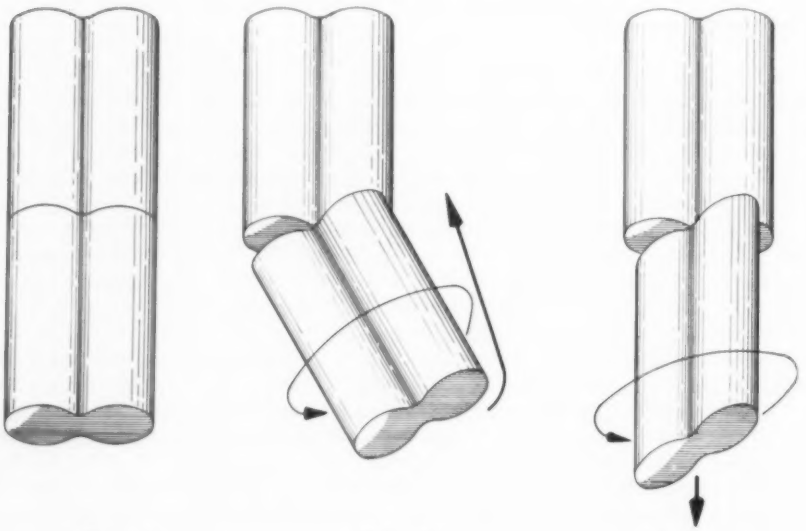

FIG. 6-A FIG. 6-B FIG. 6-C

Fig. 6-A: Mechanical drawing to illustrate the effects of rotation on the alignment of a transverse supracondylar fracture.

Figs. 6-B and 6-C: The bearing surfaces are reduced with minimal amounts of rotation; and, if a compressing force is acting, angulation is inevitable. Traction prevents angulation.

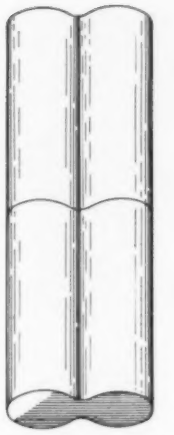

FIG. 7-A

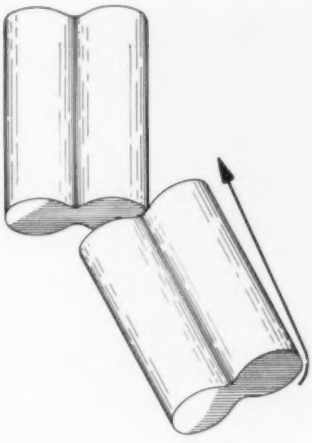

FIG. 7-B

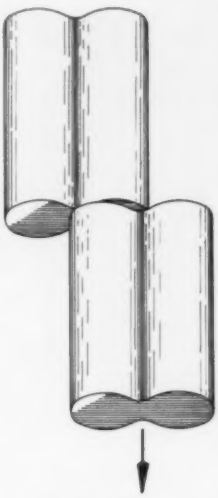

FIG. 7-C

Fig. 7-A: Mechanical drawing to illustrate the effect of medial or lateral displacement of the distal fragment.

Fig. 7-B: If the fragments are under compression, displacement of the fragments will render the column unstable, with the result that tilting occurs.

Fig. 7-C: Traction eliminates the tendency to tilt.

2-A). A similar loss in a child who started with 10 degrees of valgus would not be noticeable. The final appearance depends on the starting point.

VARIOUS DISPLACEMENTS OF THE FRAGMENTS AND THEIR EFFECT ON THE CARRYING ANGLE

To determine the effect on the carrying angle caused by various types of displacements of the distal fragment, an experiment was carried out using an articulated right upper extremity. A transverse supracondylar fracture was simulated by an osteotomy through the supracondylar region, the fragments being held together by a steel spring. The distal fragment was displaced in various ways, and the influence of each position on the carrying angle was determined. The results are shown in Figures 4-A through 4-F. It is apparent that only medial or lateral tilt of the distal fragment changes the carrying angle. However, other displacements may lead to or contribute to tilting under certain circumstances. The following examples may be cited:

With an oblique fracture (Fig. 5-A) and smooth fracture surfaces under compression, as would occur with normal muscle tone and the elasticity of the surrounding soft tissues, any rotation about the longitudinal axis of the humerus will inevitably produce tilting, as shown in Figure 5-B. Rotation of this type can readily occur in a long arm cast with the elbow in any degree of flexion. The greater the degree of obliquity of the fracture, the more will be the tilt produced by a given amount of rotation *. On the other hand, traction would prevent this tilting, as shown in Figure 5-C.

In transverse supracondylar fractures—the so-called transcondylar (diacon-

* The amount of tilt produced by a given amount of rotation may be calculated from the following formula:

$$\text{Degrees of tilt} = \frac{\text{degrees of rotation}}{180} \times \text{degrees of obliquity of fracture} \times 2.$$

For example, a fracture with 45 degrees of obliquity will tilt 7.5 degrees when rotated 15 degrees. If the obliquity of the fracture line is only 10 degrees, it will tilt 1.7 degrees with 15 degrees of rotation.

dylar) fractures—the fracture surfaces are very narrow in the anteroposterior direction. In these fractures, the bearing surfaces are small, and minimum amounts of rotation combined with compression forces inevitably cause tilting. Here again, traction will avert this tilting, as illustrated in Figures 6-A, 6-B, and 6-C.

If there is medial or lateral displacement in the presence of compression forces, the fracture will be unstable, and tilting of the distal fragment will occur, the amount of tilting being directly proportional to the amount of displacement. In this situation there would be less tendency of the distal fragment to tilt if there was no end-to-end contact. Traction will, of course, prevent this tilting, as illustrated in Figures 7-A, 7-B, and 7-C.

From these observations, it is apparent that medial or lateral displacement of the distal fragment and rotation of the distal fragment do not in themselves cause carrying-angle changes. Only tilt of the distal fragment will do so, and it can best be prevented under all circumstances by traction on the distal fragment in the direction of the longitudinal axis of the distal part of the humerus.

THE FALLIBILITY OF THE ROENTGENOGRAMS

The roentgenograms of approximately 100 supracondylar fractures of the humerus were obtained when this study was initiated, and an attempt was made to forecast the result in each case in terms of the final carrying angle. Unexpectedly, it was found that the forecasts were wrong in well over 50 per cent of the cases. A review of the available literature showed similar inconsistencies. The apparent alignment of the fragments shown in the anteroposterior roentgenograms frequently was not consistent with the final carrying-angle results recorded for the cases reported [2,4,5,16,24].

The reasons for these discrepancies appear to be (1) poor visualization of the fragments due to the plaster cast and the overlying shadows of the radius and ulna in the anteroposterior view of the flexed elbow; (2) poor definition of the small distal fragment, which is largely cartilage in the younger age groups; and (3) the influence of the position of the arm, when the roentgenograms were made, on the amount of angulation visualized.

Klinefelter stated that "angles are projected in correct size only if their axes are parallel to the plane of the film and perpendicular to the central roentgen ray." Thus, if there is any error in the exact positioning of the extremity and the exact placement of the x-ray tube and cassette, any projected angulation will be inaccurate (Figs. 8-A through 9-C). Yet this task is usually relegated to the x-ray technician, who is faced with the heroic problem of the exact positioning of a painful swollen elbow, obscured by plaster or splints, in a fidgeting, apprehensive child. If the technician misses the positioning by a few degrees one way or another, this cannot be determined from the roentgenogram, as there are no landmarks which enable the observer to state that an exact anteroposterior or lateral view of the distal part of the humerus has been obtained. Only if the roentgenograms show perfect apposition of the fracture surfaces in all views is there certainty of restoration of the carrying angle.

THE VISUAL METHOD OF TREATMENT

A completely displaced extension type of supracondylar fracture of the humerus is best treated so that the relationship between the bone prominences of the posterior surface of the elbow and the long axis of the humerus is under constant observation. If this relationship is kept similar to that exhibited by the other arm, the fracture fragments will be in proper alignment, and the carrying angles of the two arms will be symmetrical. Skeletal traction applied to the olecranon with the arm overhead allows such observation.

Obviously, splints or plaster will obscure visual judgment of the fragment alignment, and the relationship is also concealed if the skeletal traction is used

FIG. 8-A

FIG. 8-B

FIG. 8-C

Figs. 8-A through 8-C: Effect of rotation of the arm on the apparent carrying angle.

Fig. 8-A: The normal right arm of a nine-year-old boy was flexed to 70 degrees, and a plaster cylinder was applied. An anteroposterior roentgenogram was made of the elbow with the tube as nearly as possible at 90 degrees to the long axis of the arm. The apparent carrying angle was measured at about 10 degrees.

Fig. 8-B: The arm was then externally rotated a few degrees at the shoulder, and another anteroposterior roentgenogram showed an apparent increase in the carrying angle.

Fig. 8-C: When the arm was internally rotated, the carrying angle changed to an apparent varus.

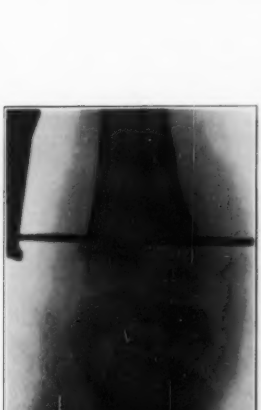

FIG. 9-A

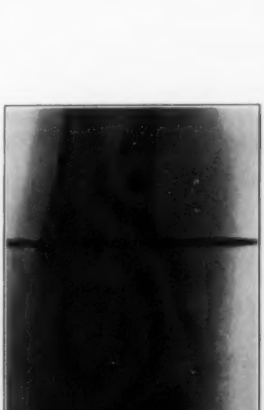

FIG. 9-B

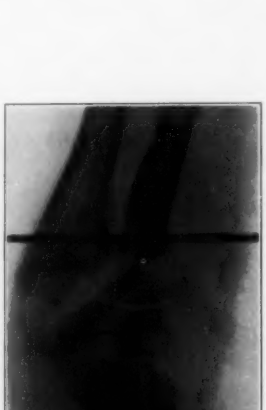

FIG. 9-C

Figs. 9-A through 9-C: Effect of positioning of the x-ray tube on the apparent carrying angle.

Fig. 9-A: Posteroanterior roentgenogram of the right elbow of a six-year-old boy. The arm had just been suspended in skeletal traction after a supracondylar fracture. By observation, it could be seen that there was a considerable uncorrected medial tilt of the distal fragment. This varus angulation is obvious on the roentgenogram.

Fig. 9-B: The arm was not disturbed, and another postero-anterior roentgenogram was made after the x-ray tube had been moved slightly toward the foot of the bed. The resulting view shows apparent improvement in the alignment.

Fig. 9-C: Another roentgenogram was made after the x-ray tube had been moved further toward the foot of the bed. Instead of varus, there is an apparent valgus angulation.

FIG. 10-A

FIG. 10-B

Fig. 10-A: Supracondylar fracture with a Kirschner wire through the olecranon; the bone prominences are aligned in conformity with the appearance of the other elbow.

Fig. 10-B: For demonstration purposes, the distal fragment has been tilted into valgus deformity.

FIG. 10-C

FIG. 11

Fig. 10-C: The distal fragment has been tilted into varus deformity.

Fig. 11: Roentgenogram of the elbow as it appeared in Fig. 10-A. Lead dots were placed on the ink markings, and a wire was taped over the long axis of the humerus. The lateral displacement of the distal fragment will have no effect on the carrying angle or the function.

in the lateral position [18] or if skin traction is used, as advocated by Dunlop.

Added advantages incident to this method of treatment are the favorable effect of constant elevation on the inevitable swelling, the easy access to the arm to check on the nerve function and circulation of the hand, and the comfort of the patient, which is shown by the fact that most children will begin to actively flex and extend the elbow within a day or two after reduction.

Theoretically, this method has the disadvantage of lack of control over the proximal fragment if the patient moves about in bed; however, this has not proved to be a problem. The younger children (three to six years of age) can be controlled by using a chest restraint which includes the shoulder. The older children avoid the discomfort attending strain at the fracture site and are usually content to remain in the proper position. This method can also be used to observe and control the position of the fragments during and after osteotomy of the humerus to correct old varus deformities. It was used in one nine-year-old girl with a 10-degree varus deformity five years after supracondylar fracture. The result was gratifying, with symmetrical elbows that each had 7 degrees of valgus and 145 degrees of motion.

DETAILS OF TREATMENT

The arm is held suspended by an assistant, with care taken not to flex the elbow, while a threaded Kirschner wire, three-thirty-seconds of an inch, is driven through the crest of the ulna one inch distal to the tip of the olecranon process. Especially in the markedly swollen elbow, it is important to identify bone landmarks carefully and select the point for insertion of the wire accurately to avoid possible injury to the ulnar nerve. It is also important that a threaded wire be used so that it cannot become loose and move back and forth in its track, with resultant danger of disaligning the fragments or introducing infection. A traction bow is made fast to the wire after it is in place, and the fracture is manipulated by applying traction on the bow in the long axis of the humerus and pressing the distal fragment forward with the thumb while the fingers make counterpressure on the proximal fragment.

Observation of Fragment Alignment

The bone prominences of the posterior surface of the elbow are palpated, and their center points are marked on the skin with ink. They are then aligned with the long axis of the humerus in conformity with the appearance of the other elbow (Fig. 10-A). Any tilting of the distal fragment can be readily visualized, as is shown in Figure 10-B, where it has been tilted into a valgus deformity, and in Figure 10-C, where it is in a varus position.

Traction Arrangement (Fig. 12)

The amount of weight applied to the traction bow depends on the weight of the arm. Enough is used to just support the arm, leaving the shoulder girdle flat on the bed; this is sufficient to stabilize the fragments. Too much weight may cause distraction of the fragments and possible neurovascular complications, as recently pointed out by Staples. The traction is applied to the olecranon in line with the distal end of the humerus, not with the shaft. To maintain proper alignment with respect to medial and lateral tilting, it is frequently necessary to attach the rope to the handle of the bow in an eccentric position. The forearm is supported in balanced suspension by using a sling, pulleys, and weights, so that the elbow is flexed at an angle of about 90 degrees and the hand is approximately over the opposite shoulder. A sling with one or two pounds of weight is applied to the arm to pull the proximal fragment posteriorly with respect to the distal fragment.

The Roentgenograms

Roentgenograms are then made to determine the amount of apposition be-

FIG. 12
The traction arrangement.

tween the fragments and the presence of rotation. If the roentgenograms show significant displacement or rotation of the distal fragment, one gentle attempt is made to correct the position by manipulation; if this is unsuccessful, no further effort is made. It is my opinion that repeated vigorous manipulations may cause some residual stiffness or damage to the epiphysis.

Edema Complicating Observation of the Bone Prominences

In these fractures, swelling about the elbow is frequently severe. In the fractures seen early, the swelling is usually confined to the anterior surface of the elbow and so does not obscure the posterior bone landmarks. However, even with severe swelling, the posterior landmarks can be palpated and marked for alignment with the long axis of the humerus. If this proves difficult, a few days of elevation in traction will usually result in considerable decrease in the edema. In such a case, it is best to elevate the hand above the elbow by maintaining the elbow in less flexion, with the forearm 20 to 30 degrees above the horizontal, and to dispense with the sling that pulls the proximal fragment posteriorly. Adjustment of the alignment of the fragments may be possible as late as fourteen days after the fracture.

Treatment after Removal of the Traction

The skeletal traction is maintained for ten to fourteen days, by which time roentgenograms usually show callus. The wire is then removed, preferably under general anesthesia, and a long arm cast is applied, with the forearm at an angle of 70 to 80 degrees with respect to the arm. It is important that the plaster be carefully molded about the olecranon to prevent late medial or lateral tilting.

ILLUSTRATIVE CASE

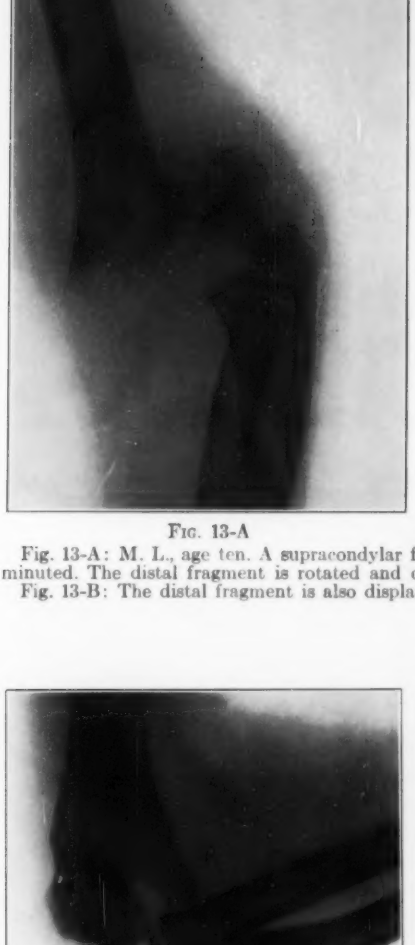

FIG. 13-A

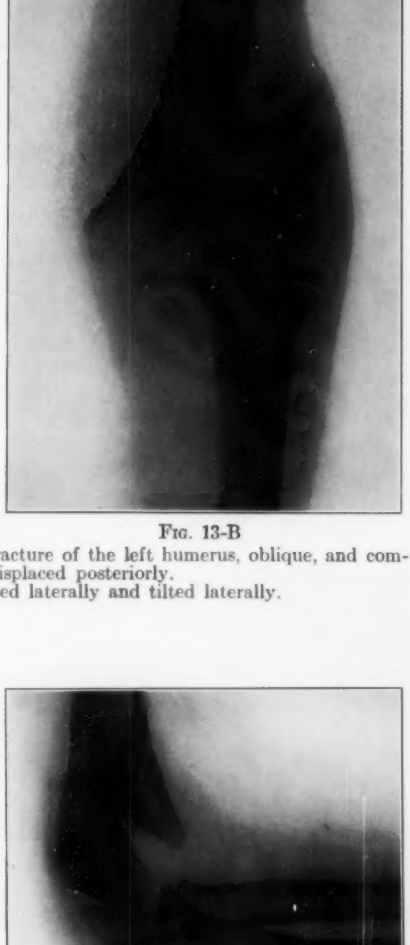

FIG. 13-B

Fig. 13-A: M. L., age ten. A supracondylar fracture of the left humerus, oblique, and comminuted. The distal fragment is rotated and displaced posteriorly.

Fig. 13-B: The distal fragment is also displaced laterally and tilted laterally.

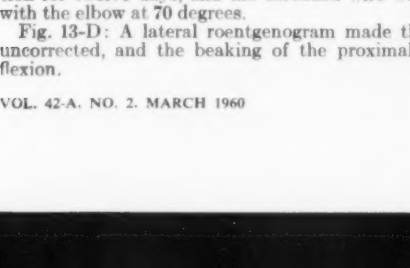

FIG. 13-C

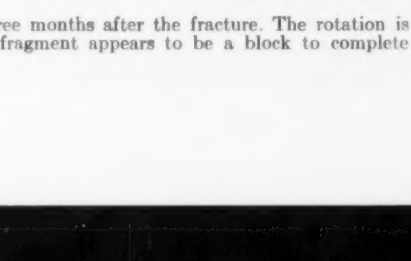

FIG. 13-D

Fig. 13-C: Fracture treated by skeletal suspension under visual control. The lateral roentgenogram showed rotation of the distal fragment which could not be corrected by gentle manipulation. However, to examination, the posterior bone contour of the fractured left elbow was symmetrical with the contour of the normal right elbow. The arm was maintained in traction for twelve days, and the threaded wire was then removed, and a plaster cylinder applied with the elbow at 70 degrees.

Fig. 13-D: A lateral roentgenogram made three months after the fracture. The rotation is uncorrected, and the beaking of the proximal fragment appears to be a block to complete flexion.

FIG. 13-E

FIG. 13-F

Fig. 13-E: A lateral roentgenogram made seven months after the fracture. The beak is absorbing, and the active range of motion is 180 degrees to 40 degrees.
Fig. 13-F: The anteroposterior roentgenogram made seven months after the fracture.

FIG. 13-G

FIG. 13-H

Fig. 13-G: The patient nine months after the fracture. The carrying angles of the two elbows are equal at 4 degrees of valgus.
Fig. 13-H: The posterior flexed view. The bone contours of the two elbows are symmetrical.

The cast is worn for an additional three weeks, and, after its removal, a sling is used for a week or so while active motion of the elbow is encouraged. Most children will regain complete range of motion within four to six months.

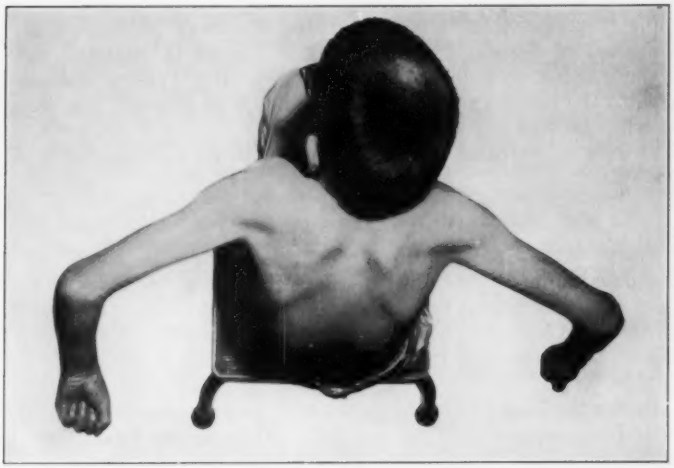

FIG. 13-I

The patient attempting to internally rotate both arms as much as possible. There is an apparent increase in the degree of internal rotation at the left shoulder.

FIG. 13-J

The patient attempting to externally rotate both arms as much as possible. There is an apparent decrease in the degree of external rotation at the left shoulder. This change is secondary to the fact that the supracondylar fracture healed with some internal rotation of the distal fragment. The change is inconsequential.

RESULTS

The method described here to observe, control, and, if necessary, correct alignment, has been used by me on twelve children with displaced supracondylar fractures of the extension type. One of the early patients gained 3 degrees of valgus and one lost 2 degrees, but the final result in the latter was a carrying angle of 4 degrees of valgus, and the change was unnoticeable. Two patients were lost to follow-up, two and three months, respectively, after the fracture. At that time they had not regained enough extension for the proper measurement of the carrying angles. However, the posterior contours of the flexed elbows were symmetrical when they were last examined. None of the other elbows showed change in the carrying angles.

Ten of the twelve fractures were examined six months after injury; all showed satisfactory function. In four of these patients the range of motion was

not complete at that time, but the greatest loss was 10 degrees of extension and 10 degrees of flexion. Only one patient had nerve damage; this was the patient who was lost to follow-up after three months. This patient showed signs of damage to the median nerve on admission to the hospital. Recovery had not occurred when he was last seen.

There were no vascular complications, and in all patients the wire was well tolerated.

DISCUSSION

If every supracondylar fracture of the humerus could be perfectly reduced and maintained so until healed, there would be no need for this study. However, many fractures cannot be reduced to hairline apposition by closed methods, and of the few that can, some become displaced subsequently. We are thus frequently faced with the decision as to what fragment position is acceptable and what is unacceptable.

To discuss the least important factor first, accurate apposition of the fracture surfaces is inconsequential. This has little effect on the final range of motion and none on the carrying angle. Blount, Attenborough, and Laurence emphasized the extensive remodeling that will occur in this age group and even compensate for complete lack of end-to-end contact in these fractures.

Rotation of the distal fragment about the long axis of the arm is of more importance, but it, too, has little effect on function and none directly on the carrying angle. It does, however, give a bizarre appearance to the roentgenogram and thus has probably led to a number of unnecessary open reductions. It is noteworthy that some authors indict rotation of the distal fragment as a direct cause of the changes in the carrying angle, yet when an osteotomy is recommended to correct severe varus or valgus changes, it is wedge, not derotation [20,21], osteotomy that is described. The fact is that rotation at the shoulder joint compensates well for any rotational deformity of the distal fragment and allows the arm to be held with the forearm in normal position.

Alignment of the fragments is another matter. Accurate alignment is of paramount importance to the final result. It is unfortunate that apposition and rotation are easily seen on the roentgenograms, whereas alignment of the fragments is often most difficult to determine accurately. This is probably the prime reason for the high incidence of changes in the carrying angle after other methods of treatment of this fracture. Open reduction and internal fixation of these fractures might appeal to some surgeons as the surest method of direct observation and control of the position of the fragments. Sandegaard, however, pointed out the technical difficulties of open reduction and reported an incidence of changes in the carrying angle of 57 per cent in his seventy-nine cases. It is not easy to convince one's self that the eye is a more trustworthy judge of fragment alignment in these cases than is the roentgenogram. However, the surgeon can prove to himself that the eye is more reliable by examining children with carrying-angle changes and comparing the appearance of the flexed elbows with the roentgenograms. This experience will stand him in good stead when he treats supracondylar fractures of the humerus by the visual method and will ensure him excellent results.

Growth Disturbance

Growth disturbance is frequently blamed as a cause of change in the carrying angle. Brewster and Karp examined eight cases of cubitus varus deformity and found that clinical measurements of the lengths of the outside of the arm exceeded those of the inside by one-quarter to three-quarters of an inch in six. They concluded that this had been caused by stimulation of the external epicondylar and capitellar epiphyses. This explanation seems most unlikely, as it has been demonstrated in this study that simple medial tilt of the distal fragment

gives the same appearance. Furthermore, it is difficult to explain the deformity on the basis of a pure growth disturbance in view of the overwhelming predominance (ten or more to one) of varus deformities. Why should the growth of the medial half of the distal epiphysis of the humerus be arrested so much more frequently than that of the lateral half, when the fracture is commonly equidistant from both or, conversely, why should the fracture stimulate growth of the capitellum so much more frequently than that of the trochlea? Although the roentgenograms of a healed fracture with cubitus varus commonly show irregular ossification of the trochlea, these changes may well be the result of disalignment and disturbed joint mechanics rather than growth disturbance. Only if the deformity increases with growth can it be attributed with certainty to growth disturbance. In an analysis of 292 fractures, Siris found the cartilage plate to be involved in only twenty-one, and of these only twelve showed a growth disturbance. The conclusion seems warranted that growth disturbance is a rare complication and seldom is the cause of a change in the carrying angle.

CONCLUSIONS

Change in the carrying angle of the elbow after supracondylar fractures of the humerus is caused by medial or lateral angulation of the distal fragment.

The angulation may be obscured on roentgenograms, but it is obvious to inspection of the posterior surface of the elbow in the flexed position.

The angulation at the fracture site is easily observed, corrected, and controlled when the fracture is treated by means of skeletal traction with the arm over the body.

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DISCUSSION

Dr. John J. Fahey, Chicago, Illinois: Time did not permit Dr. Smith to discuss many observations and studies that he has made regarding changes in the carrying angle of the elbow in children.

Twenty years ago, he observed in children a high incidence of cubitus varus or gunstock deformity after treatment of displaced supracondylar fractures that had been treated by manipulation and cast immobilization. He attributed this undesirable change, as others had previously, to medial rotation of the lower fragment. In instances in which an individual has little or no carrying angle, a minimum change in the carrying angle may produce a cubitus varus or gunstock deformity. The undesirable appearance of the elbow after such a change is the most frequent complaint after treatment of supracondylar fractures in children.

In one of his patients who had cubitus varus after a supracondylar fracture Dr. Smith recently observed that the olecranon process was displaced medially instead of laterally, as one would expect if the carrying angle were due to internal rotation of the lower fragment. This observation cast doubt on internal rotation of the lower fragment as the cause of the deformity. He confirmed experimentally on the skeleton that the loss of the carrying angle was due to tilting of the fragment and demonstrated that rotation of the fragment did not produce this change. Although internal rotation of the lower fragment of the humerus has been regarded as the chief cause in producing the loss in the carrying angle, on a few occasions tilting of the lower fragment has been mentioned in the literature as the cause.

Dr. Smith believes that considerable disalignment of the fragments can be present but cannot be detected by roentgenographic examination, and that by visual observation of the triangle formed by the points of the olecranon and the medial and lateral humeral condyles, even slight disalignment of the fragments can be detected and corrected by adjustment of the traction, more centrally placed on the traction bow. In order to use Dr. Smith's method, overhead traction is necessary. I prefer lateral traction because of the comfort to the patient; it permits more adequate arterial circulation and better venous drainage of the extremity; and flexion is controlled, regardless of how the patient moves. With overhead traction, if the body is not properly restrained, more flexion may occur, jeopardizing the circulation. In a recent article by Staples regarding neurovascular complications associated with skeletal traction in the treatment of supracondylar fractures in children, an acute vascular complication did not respond to overhead traction but was corrected by lateral traction. Dr. Staples has recently had a supracondylar fracture with a neurovascular complication respond with lateral traction as the primary treatment.

When the elbow is flexed and immobilized in a cast, it is difficult to interpret the roentgenograms that show lateral angulation, and the deformity becomes apparent only when the elbow is extended. With lateral traction, it is possible to obtain roentgenograms which, when carefully supervised, will give reliable information in avoiding changes in the carrying angle. It is not easy to outline a small triangle in the back of a swollen elbow, and I do not believe that this procedure will give more reliable information as to the reduction of a supracondylar fracture than will the roentgenograms made when the supracondylar fracture is being treated in lateral traction.

I believe that Dr. Smith's observation substantiates the views held by only a few clinicians in the past—that the change in the carrying angle is due to the tilt of the lower fragment. However, Dr. Smith is the first one to demonstrate that medial rotation itself does not affect the carrying angle. He has also confirmed this experimentally on the skeleton.

Dr. Smith (closing): I did not state that roentgenograms were of no value, nor did I say that it was not necessary to make roentgenograms. I think for medicolegal reasons they are necessary. The important thing in these fractures is the alignment; the alignment is easily concealed on a roentgenogram of the fracture, but it is obvious to visual observation. Now when Dr. Fahey makes a roentgenogram of one of these children in lateral traction, he uses his eye to place the x-ray tube, the arm, and the cassette in the proper position. Then he interprets the roentgenogram. Why not do that with your eye primarily?

First a note of caution about overhead skeletal traction or any type of skeletal traction. Very little weight is needed to maintain alignment in these fractures, the arm is only suspended and the shoulder girdle is flat on the bed. I believe some of Dr. Staples's complications were due to distraction of the fragments.

As far as swelling is concerned, in the cases seen early, swelling is confined to the anterior aspect of the elbow and does not obscure the bone prominences. In any event, after a few days of overhead skeletal traction, the edema will have subsided considerably. The bone prominences can then be palpated and marked for a comparison with the contour of the other elbow.

Before using this visual method of treatment, I would recommend that a surgeon examine children with carrying-angle changes and verify the statements made here today. Such practice will give him confidence in his ability to detect slight carrying-angle changes when the flexed elbows are viewed posteriorly during treatment of this fracture.

Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord

Part V

The Syndrome of Acute Central Cervical Spinal-Cord Injury Followed by Chronic Anterior Cervical-Cord Injury (or Compression) Syndrome

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Following a careful study of injuries to the spine and spinal cord, it was discovered that some of the patients exhibited neurological changes which were characteristic of two syndromes previously described, acute anterior cervical spinal-cord injury [3,5] and acute central cervical spinal-cord injury [4,6]. In turn, each one of these entities had a counterpart, chronic anterior spinal-cord injury or compression [1,7,8,10] and chronic central cervical spinal-cord injury or compression [9], respectively. The mechanisms and symptoms involved have been discussed in several previous publications [7,8,9,10].

The value of thinking in terms of these neurological patterns may be illustrated by the following two case reports. In each instance, a patient with cervical hypertrophic arthritis sustained a head injury associated with the syndrome of acute central cervical spinal-cord injury without fracture or dislocation of the cervical spine. Both patients recovered from the acute phase of trauma only to present, a year or several years later, a chronic anterior cervical spinal-cord injury or compression syndrome.

Case 1. P.G., a contractor, fifty-six years old, slipped on the ice in February 1954 and struck his head. When he regained consciousness ten minutes later he noted that he was numb from the neck down and that he could not move his trunk or extremities. After lying on the ice unattended for a time he began to recover muscle function. Strength in his legs returned over a period of ten or fifteen minutes. After thirty minutes he could elevate himself on his elbow. Approximately forty-five minutes after regaining consciousness, he found that he could use his hands. The numbness over his extremities and trunk also gradually disappeared. After an hour he was found and was taken to an osteopathic hospital. Roentgenographic examination revealed no fracture or dislocation of his cervical spine which showed hypertrophic arthritic changes. He was told that he merely had a stiff neck.

For a period of one year following the accident, the patient was perfectly well. Then he began to notice some numbness and tingling in the ulnar distribution of the left hand, which slowly progressed to include the palm and middle finger. He had little or no impairment of the left thumb and index finger. About four weeks before admission to University Hospital on December 28, 1956, he began having similar symptoms in his right hand. These progressed to involve the outer three fingers of the right hand. Gradually, sharp shooting pains developed in the right elbow, which were accentuated by exercise and were definitely exaggerated at night. For six months prior to his admission to the hospital he had some stiffness of his neck. Initially, he was not concerned about his symptoms for he had had mild symptoms related to cervical arthritis for a period of ten years, and there had been minimum progression of his symptoms during this time. Now, however, on hard coughing or sneezing, severe, sharp, shooting pains developed in his arms, trunk, and legs—an experience which he described as like a "nerve explosion". His bladder function was not impaired.

There was slight discomfort on percussion over the neck. He had hypalgesia over the ulnar distribution of the hand and palm, bilaterally. On the left side this included the middle finger. Position and vibration sensations were intact. He had symmetrically hyperactive reflexes in both upper and lower extremities. Signs of involvement of the pyramidal tracts were

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Lateral cervical-spine roentgenogram showing marked hypertrophic spurring at the middle and lower cervical vertebral interspaces.

Fig. 1-B: Anteroposterior view of cervical myelogram demonstrating a mid-line lesion at the fifth cervical-sixth cervical interspace with almost complete blocking of the subarachnoid space.

elicited in both upper extremities with equivocal evidence of similar involvement in the right lower extremity.

Roentgenograms of the cervical spine demonstrated marked cervical arthritis at the mid-cervical interspaces (Fig. 1-A).

On January 2, 1957, a myelogram was performed. A jugular vein-compression test prior to instillation of the contrast medium demonstrated a partial blockage of the subarachnoid space. Pantopaque was instilled, and filling defects were noted as incidental findings in the lumbar area at the third lumbar-fourth lumbar, fourth lumbar-fifth lumbar, and fifth lumbar-first sacral interspaces. With the patient's neck slightly hyperextended the pantopaque was run upward to the fifth cervical-sixth cervical interspace where it met an obstruction and would not pass despite ten minutes with the head tilted downward at a 45-degree angle (Fig. 1-B). When the patient was rolled to one side into the oblique position the fluid moved higher, but there was still persistent anteroposterior thinning of the column of contrast medium which extended from the third cervical-fourth cervical through the fifth cervical-sixth cervical interspaces. On the lateral view the filling defects at the third cervical-fourth cervical, fourth cervical-fifth cervical, and fifth cervical-sixth cervical interspaces were vividly demonstrated (Fig. 1-C).

On the day after the myelogram, a complete laminectomy was performed which extended from the second to the eighth cervical vertebrae. After incision of the dura in the mid-line and of the arachnoid laterally the spinal cord was observed to be flattened with a decrease of its anteroposterior diameter. The denticulate ligaments were cut bilaterally which released the cord sufficiently to permit its gentle retraction. The fourth, fifth, sixth, and seventh cervical-nerve roots on the left side were swollen and abnormally blanched. They were decompressed by chiseling away the bone from beneath them laterally and by carefully removing the hypertrophic ridges medially. This was accomplished with difficulty. The posterior longitudinal ligament was incised longitudinally parallel to the lateral margin of the dura covering the cord. Scoville flat root retractors were placed so that one covered the nerve

FIG. 1-C

FIG. 1-D

Fig. 1-C: A lateral view of the cervical myelogram exhibiting simultaneous encroachments on the spinal canal anteriorly by the hypertrophic spurs and posteriorly by the ligamentum flavum.

Fig. 1-D: Roentgenogram, made approximately three years after operation, demonstrates the extensive cervical laminectomy. There had been further degenerative arthritic changes without evidence of any spinal instability.

root and the other protected the dura over the cord. Then fine oral-surgery chisels and gouges were used to cut away the hypertrophic spurs from under the "axilla" and from under the "shoulder" of each nerve root. This left a trough under each root. Where there was a medial ridge extending all the way across the floor of the spinal canal, a trough was cut on each side under the roots and then the central bone was curetted and broken down into this trough to form a tunnel from either side.

This is a tedious process requiring fine, sharp instruments. Mayfield advocated the use of a downward-biting curette to scrape the osteophytes and ridges from the posterior margins of the vertebrae. This method is somewhat cumbersome and requires a rather extensive laminectomy. Furthermore, the insertion of the Mayfield curette is somewhat awkward and difficult. An electric dental drill has been used on occasion by me, but the mere catching of a piece of loose areolar tissue in the epidural space on the drill has caused this instrument to deflect dangerously toward the cord or nerve roots, and I have abandoned this technique.

In this patient, P.G., marked adhesions were found around the right cervical-nerve roots, which were freed without difficulty. It was not necessary to remove any bone on this side. The intervertebral foramina were inspected carefully to ensure complete decompression of the nerve roots. The dura was readily closed.

Postoperatively, the patient's strength in his left hand and arm improved, but he had some residual weakness in his shoulder. The pain in the right arm was relieved. There was some residual pain in the neck and slight unsteadiness in gait. Hypesthesia was present in the distribution of the left eighth cervical nerve. Reflexes in the upper extremities were hyperactive.

On follow-up examination one year after operation the patient still had some slight weakness in the left shoulder but there was a diminution in spasticity and in the severity

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Lateral cervical roentgenogram made shortly after injury on February 12, 1950, showing hypertrophic spurring of the vertebral bodies at the fourth cervical-fifth cervical, fifth cervical-sixth cervical, and sixth cervical-seventh cervical interspaces with posterior impingement on the spinal canal. Note the anterior bridging of the fifth and sixth cervical vertebral bodies.

Fig. 2-B: Six years later, lateral roentgenogram of the cervical spine showed an almost complete obliteration of the fifth cervical-sixth cervical interspace with an increase of hypertrophic spurring at the fourth cervical-fifth cervical, fifth cervical-sixth cervical, and sixth cervical-seventh cervical interspaces.

of the pyramidal-tract signs. About 85 per cent of his neck pain and all of his radicular pain had disappeared.

This patient was again examined in December 1959, almost three years after operation. At this time he had no neck pain, but did have what was first thought to be radicular pain over the right shoulder. Further investigation revealed limitation of shoulder motion which was characteristic of chronic subdeltoid bursitis. A bruise to the right shoulder, with inadequate movement of the extremity after this, appeared to be the cause of this condition. After four deep-x-ray treatments and appropriate exercises, his pain was beginning to subside. The strength in his extremities had increased and there was less spasticity, but the residual hypesthesia and symmetrical hyperreflexia noted at the previous examination still persisted. Follow-up roentgenograms of the cervical spine showed the extensive laminectomy without any evidence of instability (Fig. 1-D).

During the winter months, the patient was unable to find work but in the summer of 1959 he was able to help his wife run a sight-seeing boat and earn a part of his living.

CASE 2. F.W., a man, fifty-two years old, was admitted to a Detroit hospital after an automobile accident on February 11, 1950. He had been thrown forward against the dashboard of the car and had sustained lacerations of the face, forehead, and scalp, as well as a severe cervical spinal-cord injury. Although he complained that he was unable to move his arms and legs, on careful examination it was found that he had some motor power in his

FIG. 2-C

FIG. 2-D

Fig. 2-C: Cervical myelogram, made with the cervical spine in hyperextension, six years after injury. It reveals impingement on the cervical spinal canal anteriorly at the second cervical-third cervical, third cervical-fourth cervical, fourth cervical-fifth cervical, and sixth cervical-seventh cervical interspaces by hypertrophic spurring of the vertebral bodies and posteriorly by the wrinkled ligamentum flava. The fifth cervical-sixth cervical interspace appears to be obliterated.

Fig. 2-D: Lateral roentgenogram of the cervical spine made thirty-three months postoperatively, revealing the laminectomy from the third through the seventh cervical vertebrae. The degenerative changes of the vertebral bodies with obliteration of the fifth cervical-sixth cervical interspace are essentially the same as in the preoperative roentgenograms. There is no instability of the spine.

left lower extremity, very slight motion in his right lower extremity, and no movement of his forearms and fingers. He had hypalgesia over the entire trunk and all four extremities. There was paralysis of the triceps muscles bilaterally but strength in his biceps muscles was intact. His Achilles and patellar reflexes were symmetrical and intact, but there were bilateral extensor plantar reflexes and ankle clonus.

Roentgenograms of the cervical spine revealed hypertrophic spurring of the vertebral bodies at the fourth cervical-fifth cervical, fifth cervical-sixth cervical, and sixth cervical-seventh cervical interspaces with protrusion posteriorly into the cervical spinal canal. There was also osseous bridging between the involved vertebral bodies anteriorly (Fig. 2-A).

A neurosurgical consultant recorded these neurological findings on the third day after injury and stated that the patient had such a bizarre group of findings that he believed the patient was at least partly hysterical or malingering. On lumbar puncture a clear, colorless fluid was found with normal manometric studies. Four days after injury the patient showed more movement in the lower extremities than in the upper ones. On the fifth day after the accident he began to move his arms and fingers, and by March 2, 1950, he was able to feed himself. Four days later he was discharged from the hospital, wearing a neck brace.

Six years after the accident, on April 2, 1956, the patient was admitted to University Hospital because of increasing weakness in his lower extremities. He stated that he had attained his maximum degree of clinical recovery to the point where he could work at odd jobs, two years after his injury, when his present symptoms of weakness began to appear. Since the accident he had noted a sensation of "trying to move against resistance as though there was a band around the legs". He had marked atrophy and weakness of the left triceps muscle and all of the forearm muscles. There was marked impairment of his performance of the left finger-to-nose test. He had hypesthesia and hypalgesia on the left which extended up to the sixth cervical dermatone, and hyperesthesia on the right which extended up to the sixth cervical dermatome. There was a loss of vibration sense over both lower extremities and the trunk, but position sense was intact. He had bilateral signs of involvement of the pyramidal tracts in both the upper and the lower extremities.

A roentgenogram of the cervical spine made on April 5, 1956 (Fig. 2-B), showed almost complete obliteration of the fifth cervical-sixth cervical interspace and an increase in the hypertrophic spurring at the fourth cervical-fifth cervical, the fifth cervical-sixth cervical, and the sixth cervical-seventh cervical interspaces when compared with the initial post-injury roentgenograms made six years previously (Fig. 2-A). A cystometric examination revealed uninhibited contractions of the bladder after it was filled to a capacity of 500 cubic centimeters. A lumbar puncture demonstrated no block in the subarachnoid space on manometric examination. The total protein was thirty milligrams per 100 cubic centimeters. Cervical myelography with the neck in hyperextension demonstrated filling defects anterior to the spinal cord at the second cervical-third cervical, third cervical-fourth cervical, fourth cervical-fifth cervical, and sixth cervical-seventh cervical interspaces due to the presence of osteophytes anterior and inward wrinkling of the ligamentum flavum posterior to the cord (Fig. 2-C). There was also a mid-line defect at the level of the fifth cervical-sixth cervical interspace. Surgical exploration was temporarily deferred, and the patient was discharged with his neck supported in a Forrester collar.

Seven months later he was readmitted to University Hospital complaining of increasing weakness of his legs and a sense of increasing tightness and heaviness of his lower extremities. He had a sensation of numbness over the entire left hand, requiring him to observe the hand closely in order to perform coordinated movements. The triceps muscle was atrophied bilaterally. He had bilateral signs of involvement of the pyramidal tract in both the upper and the lower extremities with bilateral sustained ankle clonus. There was an area of hypesthesia which included the fifth cervical through the third thoracic dermatomes. A lumbar puncture revealed a clear, colorless cerebrospinal fluid without evidence of block on jugular-vein compression.

A complete laminectomy was performed on November 12, 1956, with removal of the laminae of the fourth, fifth, sixth, and seventh cervical vertebrae, bilaterally. The dura was found to be very tight over the spinal cord which was displaced posteriorly at the seventh cervical segment. After incising the dura in the mid-line, three pairs of denticulate ligaments were sectioned, and the spinal cord gently retracted to demonstrate the spurs on the fifth, sixth, and seventh cervical vertebrae protruding posteriorly into the spinal canal. By the use of a fine chisel and gouge with the technique already described, the hypertrophic spurs were removed on the left at the fourth cervical-fifth cervical interspace and on both sides at the sixth cervical-seventh cervical interspace, decompressing both the cervical-nerve roots and the cervical spinal cord. The dura was then closed.

Postoperatively, the patient had increased spasticity in the lower extremities and severe pain in the arms, but within three weeks these symptoms had disappeared and his lower extremities were stronger. At the time of discharge from the hospital he was walking well, had good strength in all his extremities, and had marked diminution in his spasticity. There was no longer sustained ankle clonus. The patient was pleased with the operative result and believed he was continuing to improve rapidly.

Ten months after operation the patient stated that he was continuing to have increased strength in his extremities, particularly the upper ones. There were some periodic aches in his lower extremities. His bladder and bowel functions were perfect. On examination he had bilateral triceps weakness but good strength in the biceps muscles. There was slightly increased tonus in the lower extremities but excellent strength. There was hypesthesia over the seventh and eighth cervical dermatomes bilaterally. Although the deep reflexes in the lower extremities were symmetrically hyperactive with bilateral abortive ankle clonus, he had only equivocal extensor plantar reflexes. There was a slight diminution in vibration and position senses in both lower extremities. The Romberg test was positive. His gait was good, and he walked well.

Thirty-three months after laminectomy the patient was re-examined. It was amazing to discover that he had no spasm or rigidity in his upper or lower extremities. His grip was good, and he walked about readily. There were zones of hypalgesia in the sixth and seventh cervical dermatomes over the left upper extremity and over the fourth lumbar, fifth lumbar, and first sacral dermatomes in the right lower extremity. Although position sense was present in both great toes, vibration sense was absent over both ankles, the patellae, and the iliac

crests. He had bilateral signs of pyramidal-tract involvement in both the upper and lower extremities with generalized symmetrical hyperreflexia. Lateral cervical-spine roentgenograms showed no instability of the spine (Fig. 2-D).

The patient improved markedly. He was raising vegetables, and his chief complaint was that he could not work in his garden for more than two or three hours at a time without becoming fatigued.

COMMENT

Both patients had sustained acute injury to the central cervical spinal cord. Both had hypertrophic arthritis of the cervical spine and both had sustained injuries to the cervical spine without any evidence of fracture or dislocation [4,6]. In Case 1, the patient fell backward, striking his occiput on the ice. Presumably, his neck was first acutely flexed and then snapped backward into hyperextension. The patient in Case 2 definitely incurred an injury in hyperextension, as indicated by the lacerations on his forehead and scalp. Presumably, the cervical spinal cord was compressed between the cervical arthritic spur anteriorly and the wrinkled, protruding ligamentum flavum posteriorly, resulting in destruction of the central zone of the cord, with surrounding edema. Since the nerve fibers to the fingers, hand, and arm lie more medially in each lateral corticospinal tract than do those to the trunk and lower extremities, recovery follows the characteristic pattern of this syndrome with movement of the lower extremities returning first, followed next by the return of bladder function and then by motor power in the arms and hands. In both patients this pattern was followed. In Case 1, function returned almost completely within an hour; whereas, in Case 2, a period of at least three or four weeks elapsed after the injury before the patient began to use all four extremities satisfactorily, and complete function never was regained. It is interesting to observe that in Case 2 the neurological pattern was so confusing that a qualified neurosurgical consultant made a diagnosis of hysterical overlay.

An interval of a year elapsed, during which both patients were able to perform their tasks fairly well, but eventually in both there developed neurological symptoms and signs indicating not only cervical-nerve-root compression but chronic anterior cervical spinal-cord injury or compression [1,8,9]. These symptoms consisted of increasing spasticity and weakness of the extremities with bilateral hyperreflexia and extensor plantar reflexes. In Case 1 the distribution of the hypesthesia indicated involvement of cervical-nerve roots, but in Case 2 there was a dermatomal sensory level indicating anterior spinal-cord compression.

The symptoms are due to an area of chronic localized compression of the anterior cervical spinal cord in the mid-line by hypertrophic arthritic spurs with secondary zones of stress in the lateral corticospinal tracts due to the pull of the denticulate ligaments at their insertions [1].

In Case 2, it was possible to compare roentgenograms of the cervical spine made at the time of injury with those at the time when the patient was first seen with chronic symptoms. It was apparent that progressive bone changes had developed. In both patients the cervical myelograms demonstrated that with the neck in extension the cervical cord was squeezed between a hypertrophic spur in front and a wrinkled ligamentum flavum behind. Therefore, cervical myelography must be undertaken with great care in such patients to avoid sudden or forcible hyperextension of the cervical spine which may do further damage to the already partially compromised spinal cord.

Both patients were subjected to cervical laminectomy with removal of the protruding bone spurs and ridges anterior to the spinal cord and both were improved. Contrary to expectations, Case 2, the patient who had sustained the more severe acute central cervical-cord injury and who had the more marked neurological changes, obtained the better result from operation, as shown by long-term evaluation. Surgical intervention in patients who have sustained both acute and chronic traumatic insults must be undertaken with the greatest caution to avoid increasing neurological disability. The nerve roots or spinal cord, already

somewhat compromised by scarring and perhaps having only a marginal blood supply, will not tolerate injudicious or prolonged retraction.

There is every reason to believe that both of the patients reported here would have had further progression of their neurological symptoms and signs if they had not been operated on. They both seemed to derive considerable relief from the operation, judging from their condition at the time of re-evaluation thirty-five and thirty-three months postoperatively.

SUMMARY

Case reports are presented of two patients who made satisfactory recoveries from acute central cervical spinal-cord injuries.

One and six years later, respectively, chronic anterior cervical-cord injury or compression syndromes developed. After decompression of the cervical spinal cord and nerve roots by laminectomy and chiseling away of central bone ridges and spurs each patient had significant improvement in his clinical condition.

The value of thinking in terms of neurological syndromes is indicated, for it aids the surgeon in selecting the proper type of therapeutic approach.

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The Versatile Cross-Finger Pedicle Flap*

A Report of Twenty-six Cases

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Significant, although often small, loss of the soft-tissue covering of a finger or thumb as the result of trauma or a surgical procedure is not an uncommon defect. The need for the earliest possible re-covering of such defects is axiomatic. It is the purpose of this paper to re-emphasize the usefulness and versatility of the cross-finger pedicle flap in the resurfacing of the volar, dorsal, and tip surfaces of the fingers or the thumb.

Proper surgical management requires careful consideration of the advantages and disadvantages of all the methods available to provide such cover. Numerous authors have discussed the various methods available for this purpose, including allowing spontaneous regrowth of skin over the defect, with or without the aid of traction on the skin; free skin grafts of various thicknesses; closure of the defect, using adjacent tissues with or without shortening of the digit; and closure with pedicle flaps from afar. Each method has its advantages as well as its disadvantages but none achieves complete restoration. The exclusive use of any one method cannot be advocated since each serves a useful purpose under proper conditions.

Under certain circumstances a pedicle flap of skin and subcutaneous tissue will provide the maximum in function and the best appearance. In general, pedicle flaps are indicated when bone or joint surfaces are exposed; when flexor tendons and, occasionally, extensor tendons are exposed; when there is need for soft-tissue padding; or when secondary reconstructions are anticipated. In certain situations pedicle-flap coverage may be contra-indicated. In general, elderly patients are not good candidates for such procedures. Hands showing degenerative or other arthritic changes do not tolerate these procedures well. Generalized circulatory changes in the hands or local changes in the involved fingers would contra-indicate such procedures, as would scarring in the donor areas.

Traditionally, when a pedicle flap is needed to cover smaller surface defects on the digits, palmar or thenar pedicle flaps have been used, whereas larger defects have been covered with flaps from the opposite arm, the clavicular or chest area, or the abdomen. The palmar flaps all too often create donor-site tenderness or unstable scars on the working surface of the hand. In addition, the position of acute flexion of the recipient digit during the period of attachment of the pedicle flap often creates joint stiffness to a disturbing degree. These flaps produce excellent coverage on the recipient digit with fairly good return of sensation because of the functional and sensory similarity of the transferred tissues to those normally present on the digits. Cross-arm pedicle flaps have certain advantages; they provide an adequate supply of relatively thin, pliable cover and do not always require defatting. However, the awkward position of the arms while the pedicle is attached and the difficulties in maintaining this position create problems. Furthermore, the disability during the period of attachment is fairly great. These disadvantages hold true to an even greater degree for the chest and abdominal pedicle flaps which almost always require defatting and frequently become pigmented and flabby, leading to poor functional results and an unsatisfactory appearance of the reconstructed area.

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 23, 1959.

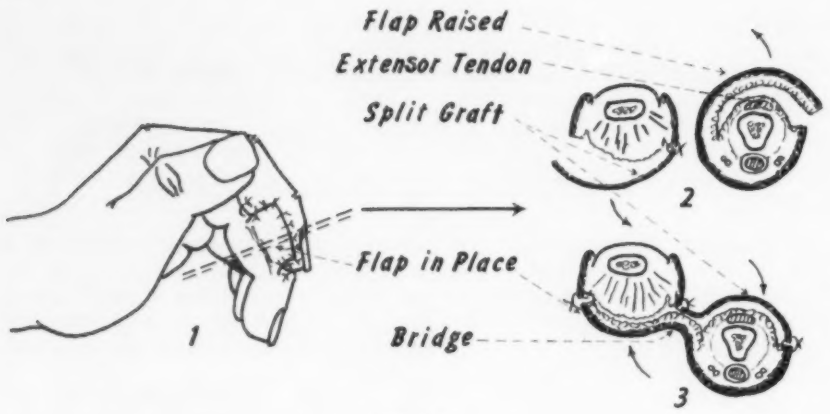

FIG. 1-A

Figs. 1-A and 1-B: The cross-finger pedicle flap.

Fig. 1-A: A laterally based, folded pedicle flap applied to the distal pad of the index finger at *1*. Drawing *2* shows a cross-section of the two fingers. The defect has been prepared, the split-skin graft is sutured to the defect only along the edge paralleling the pedicle of the flap, and the flap has been raised from the donor finger. The curved arrows indicate how the split-skin graft and the flap are interdigitated to place them in the desired positions at *3*. The split-skin graft has replaced the flap on the donor finger and the flap is supplying padded cover for the recipient finger. Note the gentle fold of the flap, the space between the digits, and the split-skin graft covering the raw surface of the bridge.

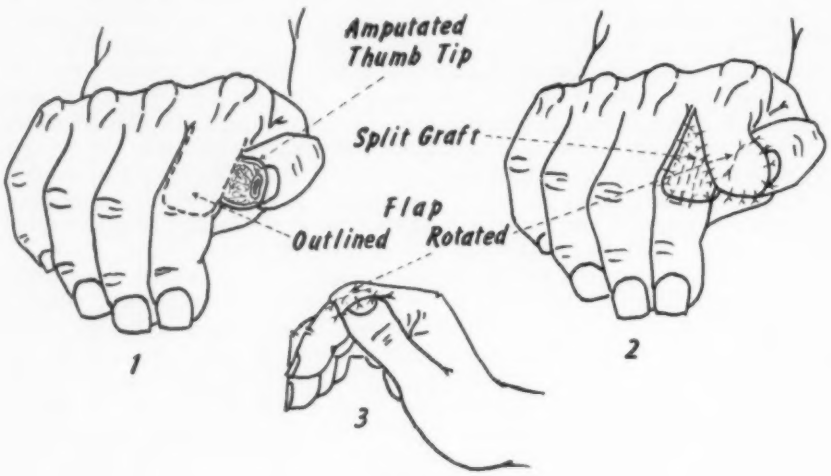

FIG. 1-B

A proximally based, rotated pedicle flap covering the thumb tip. In *1* the thumb stump is positioned so that it lies along the radial edge of the donor site for the flap, which is outlined by a dotted line. In *2* the flap has been rotated to cover the thumb stump after loosely suturing the adjacent edges of the thumb and donor defect together. Part of the flap remains on the donor finger with the split-skin graft covering the remainder of the donor defect. Number *3* is a lateral view showing the relaxed, functional position of the hand.

In the search for a method which would obviate these disadvantages, it seemed logical to turn first to the adjacent parts of the same extremity. The cross-finger pedicle flap seemed to be the obvious choice, provided it would supply functionally adequate tissues without significantly disturbing the function or appearance of the donor digit. Within the limits of the amount of cover available on any digit, this procedure has accomplished this end to an

FIG. 2-A

FIG. 2-B

Figs. 2-A through 2-E: A.A., a woman, thirty years old, with guillotine amputation in the distal portion of the distal segment of the index finger.
Figs. 2-A and 2-B: Twenty days after covering the finger tip with a distally based flap from the long finger.

FIG. 2-C

FIG. 2-D

Figs. 2-C, 2-D, and 2-E: Nine months later. Note the minimum deformity of the donor and recipient areas, and the normal range of motion of the digits involved. No defatting was necessary.

excellent, although not complete, degree. With a little ingenuity, practically any dorsal or volar area on the fingers can be resurfaced with dorsal skin and subcutaneous tissue from an adjacent finger, and most areas on the thumb can be similarly covered.

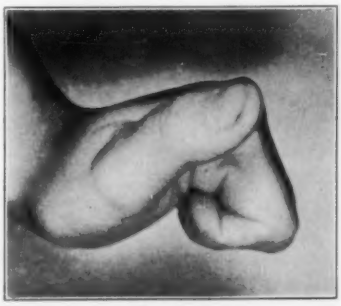

FIG. 2-E

The surgical technique is relatively simple but it demands the gentle handling of tissues, the careful hemostasis, the meticulous closure, and the attention to detail necessary for success in all tissue-grafting procedures. Under the ischemia afforded by a pneumatic tourniquet and either axillary nerve blocks or general anesthesia, the surface defect on the recipient digit is prepared by the débridement of scar and devitalized tissue. The final shape of the defect should be roughly rectangular and the margins of the defect should not cross flexion creases, even if excision or rearrangement of normal surrounding tissues

FIG. 3-A

FIG. 3-B

Figs. 3-A through 3-E: C.D., a male machinist, forty years old, with avulsion of the pad of the distal segment of the index finger.

Figs. 3-A and 3-B: Twenty days after covering the avulsed area with a laterally based flap from the long finger.

FIG. 3-C

FIG. 3-D

Figs. 3-C, 3-D, and 3-E: Seven months later. Note the minimum deformity of the donor and recipient areas, and the normal range of motion. No defatting was required.

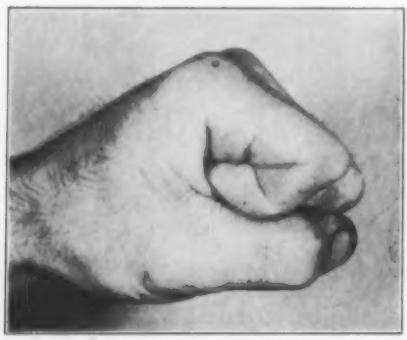

FIG. 3-E

is necessary to achieve these goals. The skin edges should be cut perpendicular to the surface of the skin and slightly undermined to facilitate attachment of the pedicle flap. Wherever possible, the volar digital neurovascular bundles should be preserved by careful dissection. If removal of all or part of the flexor-tendon sheath is necessary to accomplish proper preparation of the defect, this should be done without hesitation since the flap will afford good coverage, and the return of a surprising degree of motion can be expected. Exposed bone and

FIG. 4-A

FIG. 4-B

Figs. 4-A through 4-D: C.L., a Chinese girl, two and one-half years old, with traumatic amputation of the tip of the index finger.

Figs. 4-A and 4-B: Twenty days after attachment of a laterally based flap from the long finger to the tip of the obliquely amputated index finger.

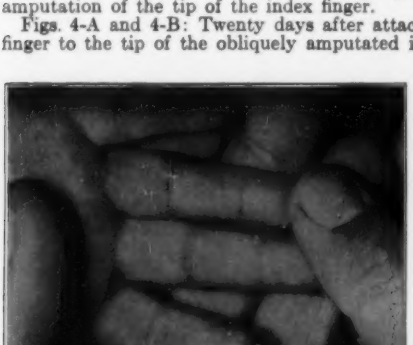

FIG. 4-C

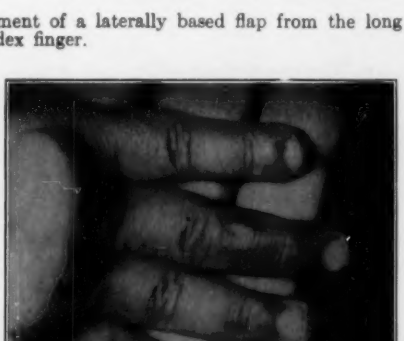

FIG. 4-D

Six months later. Note the excellent restoration of the normal contours of the slightly shortened index finger and the minimum disfigurement of the long finger.

joints can be covered readily by the flap. After the preparation of the recipient area is completed, a pattern of the defect is cut from patapar paper.

The proper donor digit and the site of the pedicle flap on that digit are chosen by placing the recipient digit in various positions about the adjacent digits to find the position of least strain. The proximal joint of the donor digit often must be rather acutely flexed to achieve minimum strain, as shown in Figures 5-A, 7-B, and 8-A. Any area on the dorsum of the proximal or middle segments of the donor digit or on the adjacent dorsum of the hand can be used as a donor site. Because of the peculiarities of circulation and the proximity of the nail root on the dorsum of the distal segment of the fingers, it is inadvisable to use this area as a donor site or to base a flap at or distal to the distal joint of the donor digit. If necessary, the recipient digit may partly cross over the donor finger (Figs. 8-A and 8-B). Tissues volar to the mid-lateral line of the donor digit are not used to avoid scarring on the work surface of the finger or damage to its volar digital neurovascular bundles. In contrast, the dorsal neurovascular bundles are functionally unimportant and may be transsected as necessary in preparation of the flap.

The flap will vary in size in accordance with the size of the defect on the

FIG. 5-A

FIG. 5-B

Figs. 5-A through 5-D: D.S., a man, twenty years old, with guillotine amputation of the thumb through the distal joint.

Figs. 5-A and 5-B: Twenty days after attachment of the proximally based and laterally rotated pedicle flap covering the stump of the thumb. Some of the flap remains over the donor index finger and is sutured to it. Only the radial portion of the flap covers the thumb defect. The excess width of the flap is necessary to maintain its circulation. The triangular defect left on the ulnar side of the donor area has been covered by a split-skin graft.

FIG. 5-C

FIG. 5-D

After six months there is no redundancy of the flap in the reconstructed area, and minimum disfigurement of the donor site.

recipient digit. The flap should be made somewhat larger than the defect. If the length of the flap will not be appreciably longer than its width, the pedicle (retained side of attachment to the donor digit) may be located in any desired direction on the dorsal half of the proximal or middle segments of the finger or on the dorsum of the hand. Longer flaps (up to a one-to-three width-to-length ratio) may be used but the pedicle (attachment) of these larger flaps must be proximal on the donor digit (Figs. 5-B, 9-A, and 9-B). These restrictions are necessary to assure good circulation in the transferred flap. Often, long flaps are left attached along one side in the mid-lateral line of the donor digit for even greater assurance of good circulation (Figs. 1-A, 3-A, 3-B, 6-A, 6-B, 7-A, 7-B, and 9-C).

When the decision as to the location of the donor site and the location of the base of the flap has been made, the previously prepared paper pattern of the recipient defect is laid on the chosen area and the flap is outlined. It

FIG. 6-A

FIG. 6-B

Figs. 6-A through 6-E: J.E., a Negro boy, twelve years old, with severe flexion contracture of the little finger due to extensive scarring of the volar soft tissues.

Figs. 6-A and 6-B: Twenty days after excision of the scarred skin and deeper soft tissue, but leaving the tendons, and re-covering with a laterally based flap from the ring finger.

FIG. 6-C

FIG. 6-D

Figs. 6-C, 6-D, and 6-E: Two and one-half years later. There is minimum disfigurement of the donor site, function is good in both digits, and, even without defatting, the graft has developed excellent contours and a new flexion crease.

must be made approximately one-eighth of an inch longer on the pedicle (attached) side than the pattern of the defect in order to form a bridge between the donor and the recipient digits. Sometimes, an even greater addition is necessary to bridge the gap between the digits, and appropriate allowances must be made for this. Some secondary additional length for the bridge can usually be provided by extending the incisions, if necessary. The proposed flap is outlined with methylene blue. Incisions are made through the skin and subcutaneous tissues on the three sides to be raised. The plane of the deep dissection is located by carrying the dissection down to the filmy areolar tissue immediately overlying the extensor tendon in the center of the dorsum

FIG. 6-E

FIG. 7-A

FIG. 7-B

Figs. 7-A through 7-E: N.E., a man, twenty-three years old, with avulsion of the distal pad of the little finger.

Figs. 7-A and 7-B: Twenty days after covering the defect with a laterally based flap from the ring finger.

FIG. 7-C

FIG. 7-D

Figs. 7-C, 7-D, and 7-E: Seven months later. The donor and recipient areas have a good appearance, and the fingers have normal ranges of motion. No defatting was necessary. Fig. 7-C shows the small split-thickness graft on the tip of the donor ring finger, which was crushed in the original injury.

FIG. 7-E

of the finger (Figs. 1-A, 3-A through 3-E, and 10-A through 10-D). At this level the flap can be mobilized with ease by blunt dissection and an excellent bed is provided for the split-skin graft which will be used later to cover the defect created by elevation of the flap. At this level the glistening white tendon is readily visible. The incisions at the free margins of the flap are deepened down to this level after the blunt dissection is completed, and the flap is turned up on its attached edge much as a book is opened. Larger flaps may extend

FIG. 8-A

FIG. 8-B

Figs. 8-A through 8-E: J.G., a woman, forty-two years old, with guillotine amputation through the distal segment of the little finger.

Figs. 8-A and 8-B: Nineteen days after the defect was covered with a distally based flap from the ring finger. Note that the fingers are partially crossed.

FIG. 8-C

FIG. 8-D

Figs. 8-C, 8-D, and 8-E: Six months later. There is minimum disfigurement of the donor site. The contours of the recipient site are excellent, and all fingers have a full range of motion. No defatting was necessary.

laterally beyond the edge of the extensor tendon. The heavier fibrous attachments between the flap and the deep fascia are best transected by sharp dissection with care taken not to make the flap too thin in these areas. The flap can now be raised, folded, or rotated into the position necessary for attachment to the recipient digit. Final adjustments may be necessary to make sure that the flap fits the recipient area without tension and without acute folding or twisting of the pedicle.

FIG. 8-E

A split-thickness skin graft somewhat larger than the defect at the donor site on the dorsum of the donor finger is then obtained, using the method most familiar to the operator. I use the Padgett dermatome for this purpose, since a uniform thickness of graft provides the best cover. The thickness of the graft

FIG. 9-A

FIG. 9-B

Figs. 9-A through 9-D: Other uses of cross-finger flaps. The cross-hatched areas mark the donor sites, strips of elastoplast represent the pedicle flap.

The procedure illustrated in Figs. 9-A and 9-B has not been used, whereas that shown in Figs. 9-C and 9-D has been used on one patient. However, this case was not included in this series because of inadequate photographs and the short follow-up at the time this paper was prepared.

FIG. 9-C

FIG. 9-D

will vary with the donor site, but approximately 16/1,000 of an inch is usually satisfactory. The volar surface of the adjacent forearm is used almost routinely, since this confines all operative procedures to the one extremity and the relative disuse of this extremity during the healing phase of the pedicle graft encourages rapid healing of the donor site for the split-thickness graft. Since the donor site for the split-thickness skin graft is, as a rule, no larger than an airmail postage stamp the resulting deformity is minimum and is in a relatively hidden location.

The tourniquet is released at this point and hemostasis carefully accomplished. Bleeding vessels on the flap must be clamped with extreme caution, using mosquito hemostats and crushing the smallest amount of tissue possible. The bleeding vessels are ligated with 00000 plain catgut throughout to minimize damage to adjacent circulation and scar formation in the fingers.

When complete hemostasis has been achieved, the tourniquet is reinflated and the split-skin graft is laid on the recipient defect as though it were to be applied to that defect. The edge of the split-skin graft along the side of the recipient defect nearest to the pedicle of the flap is then sutured to the

margin of the recipient area, using 00000 plain catgut. The split-skin graft is then folded away from the recipient defect and placed in contact with the donor site of the pedicle flap which is simultaneously folded away from its donor site and placed over the recipient site (Fig. 1-A). The split-skin graft then falls in place in the defect on the donor digit, and the pedicle flap falls in place on the recipient defect. The raw surface of the bridge of the pedicle between the digits is also covered with a split-thickness skin graft. Thus, a completely "closed system" is provided. This is important since it reduces the incidence of infection and scarring and thereby reduces tenderness and stiffness in both digits. Of course, when the flap is rotated sideways (Figs. 1-B, 5-A, and 5-B) instead of being lifted and opened like a book, as in Figure 1-A, the split-skin graft is not sutured to the margin of the defect on the recipient digit but instead is sutured to the margins of the defect on the donor digit created by the rotation, as illustrated in Figure 1-B. Usually, it is possible to place stay or retaining sutures through the skin at the adjacent corners of the donor and recipient defects proximal and distal to the edges of the flap pedicle (Fig. 1-A). These sutures help to stabilize the digits in proper position. These sutures should not be tied so tightly as to obliterate the space between the digits completely since some bridge is necessary to provide space to section the pedicle at the time of detachment. The flap is carefully sutured into place in the recipient defect with fine sutures, such as 00000 nylon, and the split-skin graft is sutured to the donor area with the same material. By the time this is completed the digits are fairly solidly attached to each other by the direct suturing and the flap attachment. The dressing illustrated in Figures 10-A through 10-D is applied for final support since it is important that the position of the fingers be maintained properly to prevent tension on the pedicle of the flap, which could cause circulatory embarrassment and perhaps even death of the transferred tissues.

The dressing is usually changed for the first time forty-eight hours after surgery. At that time most of the deep portion of the dressing, now relatively firm, is not disturbed. Only the outer layers are removed to inspect the tip of the flap to check on its circulation and to check the general position of the fingers. A dressing similar to the initial dressing is reapplied and maintained until the sutures are removed in ten to fourteen days. By that time the attachment of the flap is quite firm, and all parts of the dressing can be removed by soaking the hardened deep portions in sterile normal saline solution to soften them. Re-dressing after removal of the sutures is carried out with the same care as the initial dressing.

After three weeks (some surgeons recommend as little as ten days), under nerve-block anesthesia proximal to the affected digits and the ischemia provided by a pneumatic tourniquet on the arm, the pedicle of the flap is sectioned through the bridge with care to avoid damage to either digit. At this point the importance of maintaining a small bridge between the two digits becomes more obvious. In some instances a rather large gap is left on one or both digits after the sectioning. In all but one instance it has been possible to close the defects by undermining the skin on the side away from the transferred tissues. Obviously, one should not undermine the split-skin graft or the transferred pedicle flap since this would disturb the recently established circulation in these tissues. The undermining is carried out at a deep level, particularly on the donor finger, to avoid damage to the neurovascular bundle. In one patient a small patch of additional split-skin graft was used to close the defect on the donor digit. Since the vast majority of the wounds remain quite dry and clean throughout, rather careful closure of the two wounds can be undertaken to reduce the incidence of infection, scarring, and tenderness. As soon as primary wound healing is complete, patch dressings are applied and remobilization of the joints is started. The rapidity with which mobility of the fingers returns

TABLE I

SUMMARY OF TWENTY-SIX CASES OF CROSS-FINGER PEDICLE FLAPS

Patient	Age (*Years*)	Sex	Reason for Procedure	Length of Follow-up (*Months*)	Remarks	Rating
V.A.	58	M	Avulsion, pad of index finger	12	Hypesthesia of flap; cosmetically excellent; normal range of motion, both digits	Good
F.S.	38	M	Guillotine amputation in distal segment of thumb	13	Hypesthesia of flap with minimal dysesthesia; good contours; moderate limitation of flexion in distal joint of thumb; normal motion in donor index finger	Good
E.J.	36	M	Guillotine amputation in distal segment of thumb	15	Hypesthesia of flap; contours good; moderate limitation of motion in distal joint of thumb; normal motion in donor index finger	Good
M.B.	33	M	Guillotine amputation through distal joint of thumb	10	Hypesthesia of flap with minimum dysesthesia; good contours; normal range of motion in thumb; moderate limitation of flexion and extension in donor index finger	Fair
J.E.	12	M	Severe scar contractures, middle and proximal segments of little finger	30	Thin, soft, pliable volar cover on proximal and middle segments of little finger; good range of motion in both digits (Figs. 6-A through 6-E)	Excellent
C.D.	40	M	Avulsion, pad, distal segment of index finger	12	Hypesthesia of pad; excellent contours; normal range of motion, both digits (Figs. 3-A through 3-E)	Good
H.I.	37	M	Guillotine amputation in distal segment of thumb	11	Hypesthesia of flap with minimum dysesthesia; normal motion in thumb; slight to moderate limitation of motion in donor index finger	Fair
H.E.	45	M	Guillotine amputation in distal segment of thumb	10	Hypesthesia of flap; excellent contours; full range of motion in both digits	Good

J.H.	38	F	Old injury, tip of index finger with scarring, deformity, and tenderness	16	Hypesthesia of flap; occasional aching in cold weather; normal range of motion both digits; contours of flap good	Good
G.F.	37	M	Scarred, tender, thinly covered thumb tip; old injury	6	Hypesthesia of flap; good contours; normal motion in thumb; slight limitation of extension in joints of the donor index finger	Good
D.S.	20	M	Guillotine amputation, distal segment of thumb	12	Hypesthesia of flap; good contours; normal range of motion, both digits (Figs. 5-A through 5-D)	Good
M.M.	6	F	Congenital anomalies of fingers with scar contractures of long finger from earlier surgery elsewhere	32	Hypesthesia of flap; excellent thin, soft, pliable cover of volar surface of proximal and middle segments; some pigmentation of split-skin graft on dorsum of donor finger; motion limited by anomalies in recipient digit	Good
G.M.	24	M	Guillotine amputation in distal segment of index finger	15	Hypesthesia of flap with minimum dysesthesia; slight limitation of flexion in index finger; normal motion in donor digit; good contours	Good
R.L.	33	M	Scarred, tight, tender thumb tip; old injury	18	Hypesthesia of flap with moderate dysesthesia and aching in cold weather; generalized atrophy of thumb tissues; thumb motion slightly limited; moderate limitation of flexion in donor index finger	Poor
A.A.	30	F	Guillotine amputation in distal segment of index finger	12	Hypesthesia of flap with minimum dysesthesia; good contours; slight depression of donor site on long finger; normal motion in both digits (Figs. 2-A through 2-E)	Good
N.E.	23	M	Avulsion pad, little finger; skin loss, tip of ring finger	22	Hypesthesia of flap with minimum dysesthesia; flap slightly redundant; normal motion in both digits (Figs. 7-A through 7-E)	Good
H.W.	49	M	Amputation tip, right index finger	6	Hypesthesia in flap with minimum dysesthesia; good contours; normal motion of both digits; patient continues to practice dentistry with minimum difficulties	Good

TABLE I (*Continued*)

SUMMARY OF TWENTY-SIX CASES OF CROSS-FINGER PEDICLE FLAPS

Patient	Age (*Years*)	Sex	Reason for Procedure	Length of Follow-up (*Months*)	Remarks	Rating
J.F.	24	F	Guillotine amputation in distal segment of right thumb	16	Hypesthesia in flap; normal motion in thumb; slight limitation of flexion of donor index finger; good contours	Good
F.O.	45	M	Crushed index finger tip with oblique amputation	12	Hypesthesia of flap; excellent contours; normal motion in both digits	Good
J.G.	42	F	Amputation, tip of little finger	12	Hypesthesia of flap with minimum dysesthesia; appearance of both areas good; normal motion in both digits (Figs. 8-A through 8-E)	Good
E.W.	22	M	Oblique amputation distal segment, index finger	11	Hypesthesia of flap; good contours; normal motion in both digits	Good
C.V.	21	M	Guillotine amputation, distal segment of thumb	13	Hypesthesia of flap; good contours; normal motion in both digits	Good
C.L.	2½	F	Tip amputation of index finger	18	Excellent contours, both digits; flap slightly dark (patient is Chinese); normal motion in both digits (Figs. 4-A through 4-D)	Excellent
R.F.	21	M	Avulsion, distal pad of index finger	10	Hypesthesia of flap with minimum dysesthesia of edge of donor site on long finger; slight limitation of flexion in distal joint of index finger; normal motion in donor digit	Good
L.H.	55	M	Tip and pad avulsion, long finger	16	Hypesthesia in flap with sense of tightness; slight to moderate limitation of flexion and extension, both digits	Fair
B.R.	42	M	Avulsion, distal pad, index finger	12	Hypesthesia in flap with minimum dysesthesia; slight tapering deformity of tip of finger; normal motion in both digits	Good

FIG. 10-A

FIG. 10-C

FIG. 10-B

FIG. 10-D

Figs. 10-A through 10-D: The method of applying the dressing.

Gauze sponges soaked in saline solution are carefully packed over the flap at the tip of the index finger, over the split-skin graft on the donor long finger, between the two fingers into all the irregular spaces around the fingers, and between the partially flexed fingers and the palm (Figs. 10-A and 10-B). Dry, soft gauze is then wrapped around the two fingers and the hand. Finally, a two-inch cotton elastic bandage is applied with light pressure (Figs. 10-C and 10-D). The tip of the donor digit projects from the dressing far enough to check the circulation, but not far enough to allow motion. Thus, both fingers are immobilized by the suturing and by the molded dressing. As the saline solution dries, the inner gauze becomes quite firm to form a cast of the area for further immobilization. A plaster shell may be added, but usually this is only necessary for small children. In children, a lightweight, split plaster splint is applied to the entire arm, with the elbow at 90 degrees of flexion, and is extended over the hand dressing to prevent trauma and distal displacement of the dressing.

depends on the many variables influencing digital function. It may take as long as a year for maximum function to be regained.

As long as the reconstructed area is anesthetic it should be protected, first with patch dressings and later with adhesive tape applied directly to the flap to prevent damage. Return of protective sensation will take from six weeks to six months. Moderate hypesthesia and absence of stereognostic sense in the reconstructed areas almost always persist permanently.

Figures 2-A through 9-D demonstrate various applications of the cross-finger pedicle flap. Most have been used already while others are considered potential applications of this technique.

Between 1954 and 1958 some form of cross-finger pedicle flap was used by me in twenty-six cases, including primary repairs of traumatic injuries and secondary reconstructions (Table I). The twenty male and six female patients ranged in age from two and a half to fifty-eight years. In all patients the appearance of the reconstructed digit has been good, and the disfigurement at the donor site has been minimum. None has required defatting or secondary scar excision to obtain maximum results.

The results were considered to be excellent or good in twenty-two patients, fair in three patients, and poor in one. The criteria for these ratings were as follows:

Excellent: Full range of motion in both digits; good or excellent appearance of the graft sites; and no functional disability noted by the patient.

Good: Minimum or slight limitation of motion in the donor digit, not of a disabling degree; slight to moderate limitation of motion in the joint of the recipient digit adjacent to the area of injury; hypesthesia of flap in an important sensory area with no more than minimum dysesthesia; and good to excellent appearance of the graft sites.

Fair: Slight to moderate limitation of motion in the joints of the donor digit; moderate limitation of motion of the joints of the recipient digit, or slight to moderate limitation in both fingers; hypesthesia in the flap with more than minimum dysesthesia in either the donor or recipient area; and good appearance of the graft sites.

Poor: Moderate limitation of motion in either the donor or the recipient digit; or more than slight dysesthesia in either digit; or both of these deficiencies.

All patients have had permanent hypesthesia of the grafted areas, but this is considered a fair price to pay for the preservation of length of the digit and the maintenance of other functions. The one poor result followed a secondary reconstruction of the tip of a thumb, with disabling tenderness and dysesthesia. In this patient the flap was excellent but tenderness persisted, undoubtedly due to inadequate excision of the scarred tissue in the recipient area.

Hospitalization is usually one day for the primary operation and one day or less for the secondary operation. Because most of the patients were manual workers, the disability period averaged approximately eight weeks. Sedentary workers or those who could do one-handed work could return to work in two to three days after each stage.

ADVANTAGES AND DISADVANTAGES

The following advantages have been noted in the use of the cross-finger pedicle flap to provide soft-tissue covering for the fingers or the thumb:

1. It is a technically easy procedure to carry out in a relatively short time;
2. The flaps have routinely shown excellent viability;
3. The position of the parts is comfortable and immobilization is simple;
4. Disability is minimum since all operative areas (usually including the split-skin-graft donor site) are confined to the same extremity;
5. Hospitalization is minimum, and the patient is ambulatory;
6. No scarring or tenderness is produced by a donor site located on the palm or on the palmar surface of a finger;
7. The cover produced by the pedicle flap is adequately padded, tough, and permanent. The flap shrinks into position, producing excellent contours and almost normal appearance;
8. Secondary defatting has not been necessary to obtain maximum results;
9. The split-skin graft on the donor site is in a "silent" area on the dorsum of a finger, where it affords excellent permanent cover;
10. It is possible to produce a "closed system" during transfer, thus reducing scarring, curling of the flap, tenderness, and joint stiffness;
11. Mobility of the unaffected digits is maintained throughout the grafting procedure;
12. Postoperative tenderness of the resurfaced area is extremely rare.

The major disadvantage of this procedure is that, as with all pedicle flaps in tactile areas, there is permanent loss of good tactile sensation in the reconstructed area. Protective sensation develops, but stereognostic sensation is absent, and there is moderate reduction in the other sensory modalities as well.

In addition, slight to moderate limitation of flexion or extension, or both, occasionally may persist in one or both of the affected digits. Limitation of motion has not occurred to a disabling degree in any of these digits. The donor site of the pedicle flap occasionally will be slightly disfigured.

SUMMARY

Twenty-six consecutive cases in which cross-finger pedicle flaps were used to provide soft-tissue covering in primary and secondary reconstruction of the fingers and thumb are presented to re-emphasize the usefulness of the procedure in appropriate situations. The surgical technique is discussed and representative cases are illustrated. The many advantages and few minor disadvantages of this procedure are indicated by the results, which were good to excellent in twenty-two patients, fair in three patients, and poor in one patient. The procedure is being used with increasing frequency and regular success when coverage of soft-tissue defects on the digits of the hand by a pedicle flap is deemed desirable.

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Experimental Excision of Muscles in the Weanling Rat*

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Do changes in the mass of the other muscles occur after the experimental removal of one muscle from an extremity? One might expect an affirmative reply to this question. Yet, apparently, there has been no report in the literature of a quantitative experiment of this type. In the experimental studies of atrophy of individual muscles after denervation or tenotomy, quantitative changes in the other muscles of the extremity have not been described.

The present experiment was performed to measure the changes in the mass of the remaining muscles after the excision of the tibialis anterior of one extremity in one group of rats, and of the gastrocnemius-soleus combination (triceps surae) in another group.

METHODS

Male weanling rats, three to four weeks old, weighing fifty to 110 grams, were operated on, with nembutal, 0.03 cubic centimeter per forty grams of body weight, injected intraperitoneally as the anesthetic. The right hind leg was the operative site in each animal; the tibialis anterior was excised in one group of animals (the anterior tibialis excision group), and the triceps surae in the other (the triceps surae excision group). As controls, four animals not operated on were maintained under the same laboratory conditions. After an operative procedure, the animal was returned to its cage and was maintained on the usual diet of laboratory chow. Within several days characteristic calcaneus or equinus deformities developed in the rats, depending on which muscle had been excised. One day after operation the rats resumed active ambulation, despite some deformity of the extremity.

During the sixth week after the procedure, the animals were sacrificed. Each of the remaining muscles in the right leg and all of the muscles of the left leg were individually excised. Each muscle was removed from its attachment to bone at the origin, and the tendon was cut at the level of the malleoli. After removal, each muscle was placed in a paraffinized envelope of predetermined weight, whose edges were then pressed together to form a water-tight seal.

The muscles of the leg were grouped as follows: (1) tibialis anterior, (2) extensor digitorum longus and hallucis longus (toe extensors), (3) peroneals, (4) tibialis posterior, (5) flexor digitorum longus and flexor hallucis longus (toe flexors), and (6) gastrocnemius and soleus (triceps surae). The muscles were weighed on a semimicro balance, and the weights were recorded to the nearest milligram. The bones of the leg were removed as a unit by excision through the distal part of the femur.

Excision of the tibialis anterior entailed few technical problems because the muscles could be delineated readily and easily separated from the adjacent muscles and from the tibia. However, in one animal the muscle was incompletely removed; this animal was excluded from the reported series. In the triceps surae excision group, visualization of the sciatic nerve was necessary before excision of the muscle.

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Three animals in which the nerve was cut were excluded from the series. In the reported group of twelve animals the nerve was visibly intact at the end of the operation and at sacrifice. Postoperative atrophic skin changes which occurred in those rats whose tibial nerves were cut were not evident in the legs of these rats. Two additional animals, in which the excision of the triceps surae muscles was incomplete, were also excluded from the reported group, as were ten animals which died either during the operative procedure or within a few days. This high

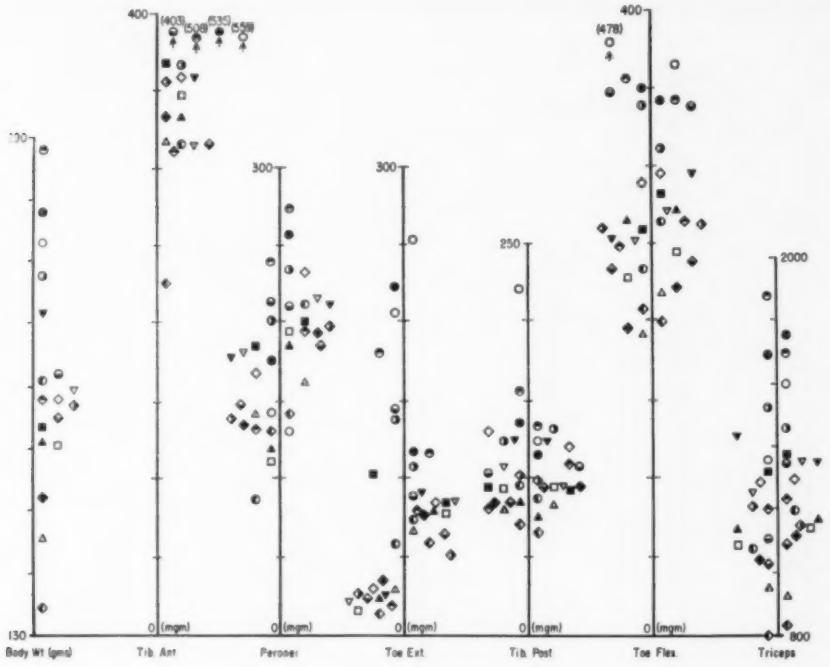

FIG. 1

Muscle weights in the tibialis anterior excision group. The body weights, in grams, of the rats are in the column at the left. The other columns are for each of the designated muscles, charted in milligrams. Each animal was assigned a different symbol. The symbols to the left of each of the vertical lines are weights for the muscles of the left leg, and those to the right are those for the right leg. The actual muscle weights for any one animal may be obtained by noting the same symbol in each column.

mortality rate is related to the unpredictable and variable effects on small rats of similar weight of a given quantity of nembutal injected intraperitoneally.

Preparation of the bones for comparison and photography after the removal of all the muscles was done by meticulous dissection of soft tissue with the aid of soaking for one or two days in 5 per cent potassium hydroxide. The bones were then bleached with sodium hypochlorite and compared grossly and with the aid of photographs.

RESULTS

The weights of the individual muscles of the experimental and the control animals are given in Figures 1 through 3. In Figure 1 the weights of the anterior tibialis excision group are presented; in Figure 2 the weights of the triceps surae excision group are presented; and in Figure 3 the weights of the control group are presented. It should be noted that, because of the different order of magnitude of

weights, the body weight is registered in grams, whereas the muscle weights are recorded in milligrams.

Three comparative studies were made of the data. First, the weight of each muscle was compared with that of the same muscle on the opposite side. The data for this study can be found in the figures by comparison of the positions of the same symbols on the left and right side of each vertical scale.

Second, the pattern of the weights of all the leg muscles in one animal was compared with that in each of the other animals, both in the experimental and in the control groups. These patterns can be visualized in the figures by following each symbol horizontally across each figure.

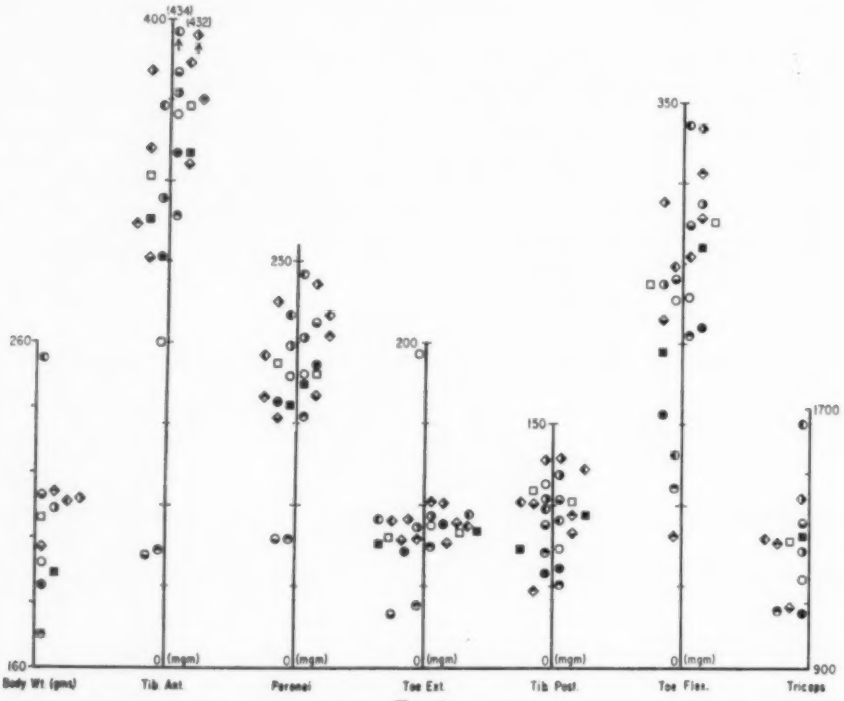

FIG. 2

Muscle weights in the triceps surae excision group. The designations are as in Fig. 1, but refer to different animals.

Third, the distribution of the weight of each specific muscle (such as the peroneals of all the anterior tibialis excisional group, for example) was compared with that of the same muscle in the control animals. In the figures, these comparisons are made by comparison of the sets of symbols to the left or right of each vertical scale in Figures 1 and 2, which record the data from the experimental animals, with the comparable sets of symbols in Figure 3, which represent the data from the controls.

SIDE-TO-SIDE COMPARISON

In the control group of four animals (Fig. 3), the values for left and right legs with respect to any specific muscle are, with only a few exceptions, in relatively close agreement. The largest single difference recorded was 11.4 per cent (toe extensors). It is of some interest that, when relatively large differences were recorded, they occurred in the muscles of larger mass as well as in those of smaller

mass. The largest mean difference was recorded for the toe flexors—6.8 per cent—but all the other mean differences were less than 5 per cent and their average was 3.9 per cent. It is well to emphasize that these mean differences in the calculations for control animals have been arrived at non-algebraically, thus maximizing their degree.

The mean differences in the experimental groups of animals varied more widely. With the exception of the tibialis posterior muscle in the tibialis anterior excision group, all the muscles on the side myectomized weighed less than those on the intact side. A few of the differences were within the range of variation of the control animals, but many exceeded this range severalfold.

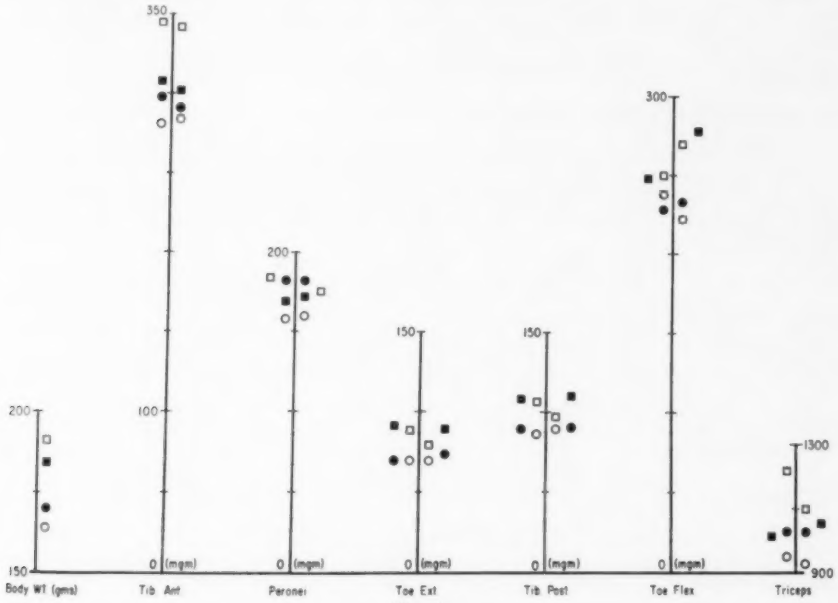

FIG. 3

Muscle weights in control animals on which no surgical procedure was performed.

For the tibialis anterior excision group, most of the muscles weighed less on the myectomized side than on the intact side. The mean differences for the weights of the peroneal, toe extensor, and triceps surae muscle groups were 22, 21, and 3 per cent, respectively. The tibialis posterior weighed slightly more on the myectomized side than on the intact side. The toe flexors were about the same in weight. These calculations of the mean differences were algebraic in order to minimize these differences and make more meaningful the comparison between them and the side-to-side differences of the controls, calculated non-algebraically. Only occasional pairs of muscles were found in which the muscle on the myectomized side was heavier than its counterpart, representing a reversal of the general trend of the muscle weights.

For the triceps surae excision group, all the muscles on the myectomized side weighed less than on the intact side. The mean differences for the tibialis anterior, toe flexors, and peroneal groups were 28, 27, and 15 per cent, respectively, as calculated from the values given in Table I.

The pattern of weight loss of the muscles was different for the two experimental groups. In the tibialis anterior excision group, the peroneals showed the greatest percentile loss, followed in order by the toe extensors, triceps, and flexors. The tibialis posterior was the one exception in this group that showed a gain in

TABLE I

MUSCLE WEIGHTS *

Muscle	Right Leg Range	Right Leg Mean	Right Leg Median	Left Leg Median	Left Leg Mean	Left Leg Range	Both Legs Mean and Standard Deviation
Control Group:							
Tibialis anterior	281 to 345	308	303	297	305	284 to 342	306 ± 23
Peroneal	158 to 184	173	176	174	172	160 to 182	173 ± 9
Extensor digitorum longus	69 to 91	79	79	76	78	69 to 89	78 ± 9
Tibialis posterior	86 to 108	97	98	94	97	89 to 110	97 ± 9
Flexor digitorum longus	229 to 250	241	243	252	251	222 to 278	246 ± 18
Triceps surae	950 to 1,217	1,052	1,020	1,041	1,026	926 to 1,097	1,039 ± 84
Group with Excised Tibialis Anterior:							
Tibialis anterior				352	368 ± 83	225 to 559	
Peroneal	86 to 239	157	146	199	202 ± 35	131 to 274	
Extensor digitorum longus	14 to 222	73	30	82	92 ± 43	51 to 253	
Tibialis posterior	70 to 220	109	98	97	102 ± 19	65 to 134	
Flexor digitorum longus	191 to 478	277	256	271	279 ± 46	199 to 365	
Triceps surae	803 to 1,872	1,241	1,200	1,259	1,280 ± 236	834 to 1,749	
Group with Excised Triceps Surae:							
Tibialis anterior	69 to 368	252	275	348	352 ± 44	278 to 434	
Peroneal	79 to 225	167	173	195	196 ± 26	154 to 242	
Extensor digitorum longus	33 to 193	84	80	88	88 ± 8	74 to 102	
Tibialis posterior	47 to 128	91	100	94	94 ± 23	51 to 129	
Flexor digitorum longus	81 to 288	197	221	275	271 ± 41	205 to 336	
Triceps surae				1,287	1,272 ± 158	1,069 to 1,652	

* Standard deviations are given for control group only, since variability in the experimental groups is excessive.

weight. In the triceps surae excision group, the tibialis anterior showed the greatest loss, followed in order by the toe flexors, peroneal, toe extensors, and tibialis posterior.

Patterns of Muscle Weights in Individual Animals

A similar and characteristic pattern of muscle weights was discernible in the legs of the controls. However, appreciable variation was evident. In the normal rats some of the muscles on the right side were invariably heavier than their counterparts on the left. Conversely, other muscles were lighter on the right than on the left side. When the differences were small, they could be attributed to variations in the amount of muscle removed at sacrifice, despite the care exercised in this procedure. Some of the differences were greater than could be attributed to variations in technique alone. The total weight of the muscles of one leg of the control animals ranged between 1.750 and 2.190 grams (average, 1.939), which represented 1.05 to 1.15 per cent of the body weight (average, 1.10 per cent). In the experimental animals the average proportion of the body weight represented by the muscles of the intact leg was almost exactly the same as that represented by the muscles in the legs of the control animals, namely, 1.10 per cent in the animals with the tibialis anterior excised, and 1.11 per cent in those with the triceps surae excised. For individual muscles in control animals the fractions of the total muscle

TABLE II

MUSCLE WEIGHTS CALCULATED AS PERCENTAGE OF TOTAL MUSCLE MASS OF THE LEG

Muscle	Control Group	Anterior Tibialis Excision Group		Triceps Surae Excision Group	
	Both Legs	Operated Leg*	Unoperated Leg	Operated Leg *	Unoperated Leg
Tibialis anterior	15.8 ± 0.4	15.8	15.8 ± 1.3	14.3 ± 3.7	15.5 ± 0.6
Peroneal	8.9 ± 0.4	7.2 ± 1.3	8.8 ± 1.2	9.8 ± 1.2	8.6 ± 0.5
Extensor digitorum longus	4.0 ± 0.3	2.9 ± 2.3	3.8 ± 1.1	4.9 ± 1.6	3.9 ± 0.3
Tibialis posterior	5.0 ± 0.3	4.9 ± 0.8	4.4 ± 0.5	5.5 ± 1.5	4.1 ± 0.7
Flexor digitorum longus	12.7 ± 0.7	12.6 ± 1.6	12.1 ± 0.7	11.9 ± 3.8	11.9 ± 0.9
Triceps surae	53.6 ± 1.0	56.6 ± 3.4	55.1 ± 1.4	53.6	56.0 ± 1.6

* Values calculated as follows: $P_{a,b} \ldots = \frac{W_{a,b}}{W_t} \ldots$ and $W_t - W_s + P_c W_t$. Where $P_{a,b} \ldots$ are the percentages represented by each muscle, the mean and standard deviation being the listed values, $W_{a,b} \ldots$ are the respective weights of each of the designated muscles, W_t is the corrected total weight of the muscles of the extremity, W_s is the cumulative weight of the weighed muscles of the extremity, and P_c is the percentage in the control group represented by the muscle missing in the operative groups (15.8 for the tibialis anterior, 53.6 for the triceps surae).

mass of the leg were as follows: triceps surae, 53.6 per cent ±1.0 (standard deviation); tibialis anterior, 15.8 per cent ±0.4; toe extensors, 4.0 per cent ±0.3; tibialis posterior, 5.0 per cent ±0.3; and toe flexors, 12.7 per cent ±0.7 (Table II). Although these patterns were fairly consistent, as evidenced by the small standard deviations, a few larger and older animals, weighing over 330 grams, showed significantly different proportions of muscle weight. This may indicate that changes in the pattern of muscle mass for leg muscles occur with age, but the data on the large animals were inadequate to show this quantitatively.

In the experimental groups, the pattern of muscle weights on the intact side showed much more variation than did the pattern of muscle weights in the extremities of the control animals; the values are listed in Table II. The large standard deviation in both experimental groups was equally evident in small and large muscles. However, the pattern of muscle weights in the intact legs of the two experimental groups of animals did not differ from that of the controls, despite the increased variability.

The patterns of the muscle weights in the myectomized legs differed significantly from the patterns in the intact legs and also from the patterns in the legs of the control animals. To facilitate comparison of these patterns, ratios were calculated with the weights of the muscle groups under consideration as the numerators and the weights of the total muscle masses of the corresponding legs as the denominators. Since one muscle was absent from each of the right legs of the animals which were operated on, proportions based on the actual weight of the leg muscles in these extremities would be different from the proportions determined for the intact legs not operated on. Accordingly, a calculated weight for the excised muscle was added to the actual weight of the remaining muscles of the myectomized legs. The calculated weight of the excised muscles was determined from the muscle weights in the control animals. The percentage of the total muscle mass in the control legs, contributed by the muscle which had been excised in the experimental animals, was determined (15.8 per cent for the tibialis anterior and 53.6 per cent for the triceps surae). This percentage was then used to determine the calculated weight of the excised muscle, and this weight was added to the actual muscle weight of the legs from which the muscle had been excised. The sum of these weights was used as the denominator for the second and fourth columns in Table II. These comparisons show that in the tibialis anterior excision group,

TABLE III

RATIOS OF MUSCLE WEIGHTS TO TOTAL BODY WEIGHT OF EACH GROUP

Muscle	Right Leg			Left Leg		
	Range	Mean	Median	Median	Mean	Range
Control Group:						
Tibialis anterior	1.67 to 1.81	1.74	1.73	1.72	1.72	1.64 to 1.79
Peroneal	0.92 to 1.07	0.98	0.96	0.96	0.98	0.92 to 1.07
Extensor digitorum longus	0.41 to 0.49	0.45	0.44	0.43	0.44	0.41 to 0.48
Tibialis posterior	0.52 to 0.59	0.55	0.54	0.54	0.55	0.51 to 0.60
Flexor digitorum longus	1.31 to 1.45	1.37	1.35	1.39	1.41	1.35 to 1.51
Triceps surae	5.50 to 6.37	5.93	5.92	5.74	5.79	5.65 to 6.04
Group with Excised Tibialis Anterior:						
Tibialis anterior	———	—	—	1.75	1.75	1.49 to 2.18
Peroneal	0.41 to 1.00	0.75	0.77	0.98	0.97	0.51 to 1.13
Extensor digitorum longus	0.08 to 0.83	0.32	0.17	0.41	0.43	0.25 to 0.99
Tibialis posterior	0.39 to 0.86	0.51	0.50	0.48	0.49	0.39 to 0.58
Flexor digitorum longus	1.09 to 1.87	1.31	1.26	1.29	1.33	1.19 to 1.59
Triceps surae	5.07 to 6.68	5.88	5.91	5.98	6.07	5.43 to 6.98
Group with Excised Triceps Surae:						
Tibialis anterior	0.32 to 1.74	1.22	1.37	1.70	1.72	1.57 to 2.04
Peroneal	0.37 to 1.06	0.81	0.87	0.95	0.96	0.85 to 1.11
Extensor digitorum longus	0.15 to 1.01	0.41	0.40	0.44	0.43	0.37 to 0.48
Tibialis posterior	0.22 to 0.60	0.45	0.45	0.47	0.46	0.30 to 0.61
Flexor digitorum longus	0.38 to 1.36	0.97	1.11	1.33	1.32	1.14 to 1.58
Triceps surae	———	—	—	6.21	6.22	5.52 to 6.90

the peroneal muscle and toe extensors accounted for slightly less of the corrected leg muscle mass; and the triceps surae accounted for slightly more. The other muscles on the side of excision did not show any significant change in their weight proportions. For the triceps surae excision group, the tibialis anterior and toe flexors accounted for slightly less of the leg mass, whereas the other three muscle groups (peronei, toe extensors, and tibialis posterior) accounted for slightly more. None of the weight changes seemed to be of biological significance because of the large standard deviations.

WEIGHTS OF SPECIFIC MUSCLES

The individual muscles in the control animals showed variations from the means for their respective muscle groups amounting to ±17 per cent of the weight (Table I). In the control animals, the muscles were not separated into right and left subgroups for calculation of averages and variability. Means and medians for the muscle weights of the control animals, given in Table II, show about the same range of variability of each muscle group. The largest muscle, the triceps surae, showed as much variation as the smallest.

For the tibialis anterior excision group, the variations of the muscle weights in the intact legs fell between ±17 per cent of the mean (Table I). For the triceps surae excision group, the muscles on the intact side showed deviations from the mean of ±12 per cent. No one muscle showed a significantly greater tendency to vary than did the others. The variability of muscle weights in the muscle groups on the myectomized side far exceeded that in the muscles of the intact extremities. The triceps surae excision group showed more variability in this regard than did the tibialis anterior excision group. (Compare the standard deviations in the second and fourth columns, Table II.)

Comparisons of the means or medians for the weights of individual muscle groups in Table I were made with the following results: the muscle groups on the intact side of the experimental animals were heavier than those of the controls.

In both experimental groups the only exception was the tibialis posterior in the tibialis anterior excision group.

A comparison of the muscle weights of the myectomized side with those of the control animals yielded no pattern of change sufficiently different from the side-to-side comparison to warrant special mention. Actual comparisons may be made from the data in Tables I and II. Computations were also made of the ratios between muscle weight and body weight and between muscle weight and leg weight and these ratios were compared. The same procedures and statistical handling were used as when the actual muscle weights were compared. A summary of the values of the ratios is presented in Table III.

CHANGES IN SHAPE OF THE BONES

The bones of the myectomized extremities showed only slight changes, most evident in the tibialis anterior excision group. In this group, uniformly, the posterior and lateral concavities of the proximal half of the tibia and the anterior concavity of the distal half were less pronounced than on the control side. The medial concavity of the distal half was increased. The anterior border of the tibia became rounded in the proximal portion. The lateral border in the distal half of the tibia swung medially and anteriorly to form a crest on the anterolateral aspect. The proximal portion of the medial surface became rounded in contrast to the distal portion which became flattened and broadened, particularly in the distal third. The lateral surface became narrower and its orientation was changed so that it faced in a more anterolateral direction. The attachment of the fibula to the tibia was more posterior than normal, and the medial concavity of the fibula was decreased. Because of this, and because of the decreased posterior concavity of the proximal half of the tibia, the interosseous gap was slightly narrowed. In the triceps surae excision group the changes were very slight and inconstant. Slight diminution of the posterior concavity of the proximal half of the tibia was observed, along with slight narrowing of the interosseous gap.

DISCUSSION

The significance of the differences in muscle weights noted in these experiments is limited by the experimental technique and by any side-to-side difference normally existing between left and right extremities. Variations in the weights obtained were minimized by careful dissection of each muscle in order to remove all of the fibers at their origins, by cutting of the tendon at the same level distally, and by the removing of adhering fascia and subcutaneous tissue from the muscle. In order to reduce loss of weight by evaporation, exposure of the specimens to the air was reduced to a minimum, and all the specimens were weighed accurately.

Differences in the weights of individual muscles in right and left legs have been noted previously by workers concerned with muscle atrophy. Langley, in 1916, weighed the individual muscles of the extremities of three rabbits and found differences of as much as 7 per cent between corresponding muscles on the right and left sides. Lipschütz and Audova, in 1921, noticed an average difference of 0.5 per cent in the fresh muscles of nine rabbits in similar comparisons. The maximum difference which they found was 6.3 per cent. Thomsen and Luco in 1944 compared the soleus and tibialis anterior muscles of seven cats and recorded an average difference of 6.3 per cent for the soleus and 3.2 per cent for the tibialis. In one cat the soleus differed by as much as 14.2 per cent, and the tibialis by 10 per cent when the two sides were compared. Ferguson, Vaughan, and Ward in 1957 reported a 6 per cent difference between the muscles of each side of twelve normal rabbits but did not indicate the ranges of differences for individual muscles. Apparently, comparisons of this type have not been made for normal rats.

The differences in the control animals in the present experiments averaged 3.9 per cent. These differences were not significantly altered when they were calculated with respect to the weight of the total muscle mass of the legs under consideration. Other statistical manipulations of these data employed by us did not reveal

additional information of value. For those interested in further statistical studies, the necessary calculations can be made from the data in Figures 1 through 3.

The first question one may ask concerning the results of these experiments is whether the changes in weight of the muscles in the myectomized extremity indicated any compensatory hypertrophy in that leg. In the experimental animals, only one muscle was heavier on the myectomized side than on the intact side. This muscle, the tibialis posterior, in the tibialis anterior excision group, showed a mean increase of only seven milligrams, and this was attributable primarily to a single exceptional animal. Were it not for this one animal, the mean weight (or median) of this muscle category would have been equal to or lighter than that of the intact side. Under the conditions of these experiments, therefore, atrophy is the rule in the remaining muscles in the myectomized extremities. It is notable that the degree of atrophy was not uniform in the different muscles of the extremity, but no meaningful pattern of atrophy could be discerned when the different muscle groups were compared.

When one of a group of synergists (the tibialis anterior, for example) was excised, one might have expected either more or less atrophy in the remaining synergists (dorsiflexors) compared with the atrophy of disuse in the antagonists (plantar flexors). More atrophy in the remaining dorsiflexors would be anticipated if they were inadequate for useful function and if, with the foot in the equinus position they became overstretched, and as a result were used less. On the other hand, less atrophy would be expected if the remaining synergists were still adequate for function and continued to function regularly or even underwent substitutional hypertrophy. The first possibility (more atrophy of the synergists) might seem to apply to the results in the tibialis anterior excision group, but it is not applicable to those in the triceps surae excision group where markedly increased atrophy in the remaining plantar flexors would be expected because of their relative insignificance with respect to normal plantar flexor muscle power. The data show that the atrophy of the dorsiflexors and of the remaining plantar flexors was approximately equal.

The second possibility (less atrophy of the synergists) did not occur. In the tibialis anterior excision group less atrophy was evident in the remaining dorsiflexors compared with that in the plantar flexors, and in the triceps surae excision group the remaining plantar flexors did not show less atrophy compared with that of the dorsiflexors. Thus, these experiments show that no substitutional hypertrophy occurred in any of the muscles in the myectomized extremity.

A second question, to which these experiments were directed, is this. In the experimental group does any compensatory hypertrophy occur in the muscles of the intact extremities? The data are not conclusive on this point. Although the percentage of body weight represented by the total leg muscle mass was the same for the intact legs in both experimental groups as for the legs of the control animals, the actual total leg muscle mass was slightly greater in the intact legs in the experimental animals than in the legs of the controls. However, when animals of approximately equal weights from the experimental groups and from the control group were compared in this respect, the difference in total leg muscle mass was very small, but this difference still favored the experimental group by about 4 per cent. This slight difference is not considered of great significance.

The pattern of muscle weights in the intact legs of experimental animals (Table II) showed some consistent differences when compared with the controls. The triceps surae group of muscles was consistently heavier while the other muscles were consistently lighter in these legs. This change in pattern indicates that the intact extremity of the experimental animals was used differently than that of the normal controls. No explanation was evident for the observation that, regardless of whether the myectomized extremity functioned in calcaneus or in equinus position, the opposite intact extremity showed an increase in weight of the triceps surae while the other muscle groups were lighter than the controls.

The question may be raised as to whether the animal's growth and development were altered sufficiently by the experimental procedure to affect the results substantially. The pertinent data in this connection are the weight gain of the respective groups of animals and the weight comparisons between muscle categories in experimental and control groups. The weight gains of the experimental group were larger on the whole than those of the control groups, although the control animals were slightly younger. With one exception, the weight gains indicated no serious disturbance in nutrition. The comparable gains in weight of several muscle groups in all three series of animals also indicate no serious interference with the growth and development of the muscle and favor altered function as the explanation for the variations.

The very slight alterations in bone contour which were observed in these experiments were not sufficient to indicate the changes in the mechanics of the limb which resulted from changes in the muscle pulls. Similar degrees of change in bone contour have been noted experimentally and clinically, but only a few reports of these are available. Bernhard suggested that the triangular cross section of the tibia was due to the action of the anterior leg muscles, whose tension developed the prominent anterior border. He described four poorly documented clinical cases of talipes equinus in which atrophy of the anterior leg muscles was accompanied by a disappearance of the sharp anterior tibial crests and the development of a rounded cross section. Fick, in 1857, noted that removal of the extensor muscles in young dogs caused the anterior margins of tibiae to develop a rounded contour. In experiments supplementary to those reported here, several animals showed marked bone changes during the same period of observation when more than one muscle group was excised. However, an insufficient number of experiments have been carried out to warrant detailed documentation of these results at this time. Changes in bone contour were observed following the excision of muscles even in adult animals. Further observations are necessary to establish the mechanisms involved.

The final question which may be pertinent here concerns the discrepancy between these results and common clinical experience. Hypertrophy of muscles which are substituted for those paralyzed is commonly seen in some patients with certain patterns of muscle weakness which have persisted for long periods. The occurrence of such substitutional hypertrophy in human beings may be ascribed in many cases to purposive exercise and a planned program of increased use of the muscles in question. However, there are cases where it occurs without such a conscious, purposeful program. The discrepancy between the occurrence in those patients of substitutional hypertrophy and the lack of this change in these animal experiments invites speculation. The most attractive explanation is that the vastly higher level of integration of the nervous system of human beings compared with that of the rat promotes a substitutional overuse of the appropriate muscles without conscious effort on the part of the patients. If this is true, it would suggest that purposeful programs of increased exercise to promote substitutional hypertrophy might offer a more certain means of attaining this hypertrophy than reliance on unconscious mechanisms. The data from these investigations serve to re-emphasize the marked discrepancies which may occur when experimental results in animals are compared with clinical situations.

NOTE: The assistance of Dr. Joseph H. Dimon, III, and Dr. Frederick A. H. Greenwood in this investigation is acknowledged.

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DISCUSSION

Correlation of Myelogram in the Clinical and Operative Findings

(*Continued from page 206*)

because this amount spans two disc spaces simultaneously and fills more adequately the larger dural sacs.

Myelography is postponed if the spinal tap is bloody. Dr. Barr has mentioned in the past the possibility of arachnoid irritation from a mixture of blood and pantopaque.

A myelogram adds to the completeness of documentation of the case. Normal spinal-fluid protein is non-informative. An elevation of 100 milligrams or more should excite suspicion of tumor.

The statistics of Lansche and Ford substantiate their contention that, if the clinical picture warrants it, exploration of the lumbar canal should be done even though the myelogram is negative.

The value of a negative myelogram may be illustrated by two young women in our series who had clinical symptoms of lumbar disc protrusion. Conservative therapy had no beneficial effect and yet with negative myelograms we were reluctant for some reason to do laminectomy. Trial cases of prostigmine bromide—0.15 gram three times daily—gave complete relief in both cases within forty-eight hours, and each had positive curare tests on later investigation.

Dr. David M. Bosworth, New York, N.Y.: Delay in operating on a fresh herniated disc is always necessary to establish differential diagnosis. Such delay should not be for a short period but should be rather extensive, with an attempt to get the patient over the original attack. There are many ways of judging where a herniation has occurred, such as clinically, by roentgenogram, and, later, by exploration.

Arachnoiditis developing from myelography does occur in certain cases. In such instances, the fact that other patients did not have arachnoiditis hardly helps the patient who does have it. The findings after arachnoiditis occurs are irreversible. To our minds it is a fallacy to state that the mild headaches occurring after pantopaque myelography are not related to myelography when the roentgenogram of the skull shows intracranial pantopaque. Even if the pantopaque is entirely removed, its previous irritating presence intradurally still remains. Actually, not all of the pantopaque is removed except in very few cases, and some residual practically always remains. Myelography should be withheld for routine disc cases and used only for cases that are not clear-cut or that might represent tumor. Exploration can be done, and, if necessary, myelography may be used in the few cases where difficulty occurs. It is not a procedure that should always precede or accompany disc surgery.

Where laceration of a disc has occurred and herniation or bulging has taken place, removal of the bulging material is not sufficient to re-establish strength in that area of the spine. A weak area remains, not only as a potential but as an actuality. Therefore, a fusion across such weak areas should always be done.

Osteochondritis of the Knee Joint

A Report of Three Cases in One Family and a Discussion of the Etiology and Treatment

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The widespread interest in osteochondritis dissecans, particularly of the knee joint, is apparent by the number of publications on the subject that have continued to appear for many years. Despite numerous clinical investigations and experimental studies, the pathogenesis of the condition still remains doubtful. The purpose of this paper is to report the cases of three brothers, all of whom had similar lesions in the femoral condyles, and to discuss the etiology, pathogenesis, and treatment. A résumé of the histories of the three patients follows:

Case 1. W.S.G., a tall, slender boy, sixteen years old, was seen on December 12, 1940. One month previously he had injured his left knee while playing hockey. A large loose body could be felt in the suprapatellar region. Roentgenograms of the left knee showed an area of decreased density in the outer part of the medial condyle.

The knee was explored on January 2, 1941. A body about two centimeters in diameter and covered with smooth cartilage lay free in the joint and was removed. There was a defect about 3.5 centimeters in diameter in the lateral inferior portion of the medial femoral condyle. Attached to the margin of this cavity by a fibrous pedicle was another body somewhat larger than the first and also covered with cartilage. A rim of bone covered by articular cartilage was all that remained of the surface of the condyle. The medial meniscus was intact, but the anterior cruciate ligament had been ruptured. The two loose bodies were removed.

This boy continued to play baseball and football despite admonitions to the contrary and later became a fighter pilot. When last heard from in 1957 he was playing squash and tennis, with only an occasional catch in his knee.

Case 2. D.G., a tall, slender boy, seventeen years old, a brother of W.S.G., was seen on January 15, 1944, because of swelling and stiffness of the left knee. He had had several injuries to the knee while playing football during the preceding four years. One week before his examination the knee locked and he felt a loose body in the joint. There was a large effusion in the left knee and a loose body was felt on the inner side of the joint. Roentgenograms showed a cavity in the medial condyle of the left knee and a small body of bonelike density in the suprapatellar region. Roentgenograms of the right knee showed a shallow excavation in the medial condyle of the femur, similar to but much larger than the one in the involved left knee. The patient had had no symptoms in this joint.

At exploration of the left knee on January 15, 1944, a loose flat body about 1.5 centimeters in diameter was removed from the inner side of the joint. In the central part of the articular surface of the medial condyle was a crater about 1.5 centimeters in diameter. This was lined by fibrous tissue. Later examination of the loose body showed that it consisted of necrotic bone covered by partially degenerated hyaline cartilage.

A report from the patient in 1957 stated that he had no difficulty with the left knee and that he was active in sports. At no time had he had any symptoms in the right knee.

Case 3. G.G., a brother of W.S.G. and D.G., a tall, slender boy, fifteen years old, was admitted to the New York Orthopaedic Hospital on June 20, 1949, because of the complaint that his left knee gave way. This had occurred for the first time two weeks previously when he was sliding for base in a ball game.

Roentgenograms showed a large, sharply outlined area of diminished density in the medial condyle of the left femur. In this area were two apparently discrete pieces of bone.

When the left knee was explored on June 21, 1949, it was seen that the articular cartilage was softened over an area on the lateral surface of the medial femoral condyle. This cartilage hung down in a fringe. Adjacent to this and more medial, the articular cartilage appeared slightly elevated and yellowish. This cartilage, together with the underlying bone, was firmer. The bone underlying the mesial area of softened cartilage seemed a little less firm, but it

was not loose or detached and no line of demarcation could be found. The soft, fibrillated cartilage was excised, but the bone was not disturbed. When last seen in 1952 the patient had no complaints and showed a full range of painless motion. He reported in 1957 that he was active in sports and still had no symptoms.

These boys were all of the same general anatomical type and all were engaged in sports which might have caused similar injuries to their knees, but that the almost identical lesion should have occurred in the same location in each of their knees without some other common underlying factor is difficult to accept. It is to be noted that in Case 2, D.G., there was roentgenographic evidence of a similar but larger lesion in the right knee, although there were no symptoms in this knee.

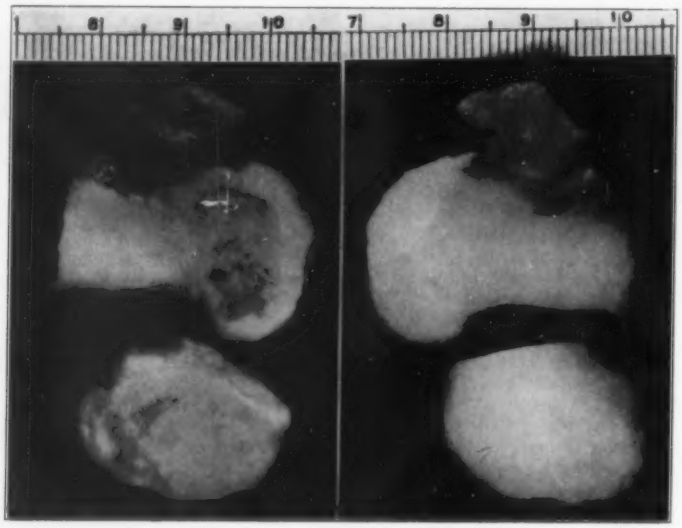

FIG. 1

Loose osteocartilaginous bodies removed from knee joint in Case 1.

The theories generally proposed regarding the etiology of osteochondritis fall into two groups. The first theory considers trauma as the primary and important factor. The second theory postulates that the etiology is an area of aseptic necrosis in the bone caused by occlusion of an artery by an embolus, with trauma playing a secondary but important role. It is my belief that actually there are two distinct varieties of this condition, each with a different etiology. In the first variety trauma is the primary and all-important cause. This form is found in adults and older children and differs from the second in that the lesion occurs in other parts of the bone and in various joints and is limited to a single incident. The second variety occurs in children before closure of the epiphysis, and the lesions are often multiple. In the knee the lesion is, almost exclusively, in the lateral part of the medial condyle of the femur. It seems probable that the lesions are the result of a systemic condition, possibly metabolic, and that they are related to osteochondritis in other bones, such as the head of the femur or in the vertebrae.

Among the advocates of the theory that trauma alone is the cause of osteochondritis dissecans was König, who was the author of the term *osteochondritis dissecans* and who thought that the cause was a shearing or blasting force. Rehbein carried out experiments on dogs in which the knee was forcibly and repeatedly hyperextended in such a manner as to exert force upon the surface of the femur through the patella. He was thus able to produce a lesion which

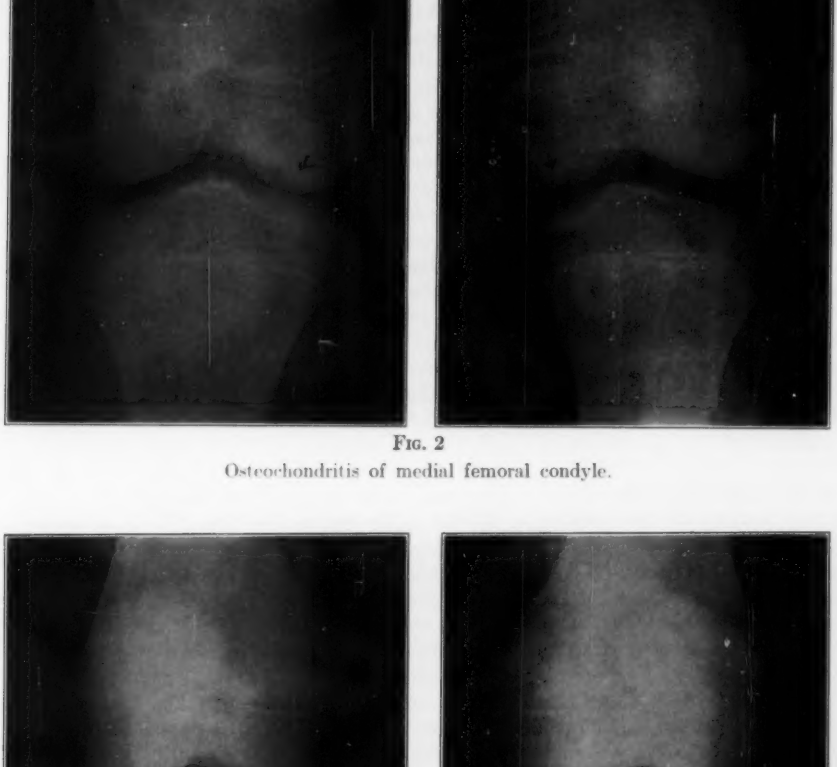

FIG. 2

Osteochondritis of medial femoral condyle.

FIG. 3

Spontaneous disappearance of lesion in medial femoral condyle.

he thought was typical of osteochondritis dissecans found in man. In a critique of this paper Axhausen [3] said that the histopathology in the cases produced in the laboratory was essentially different from that in the human being in that the fracture was through normal bone, whereas in those lesions occurring clinically it was through necrotic bone.

Buchner and Rieger, in experiments on cadavera, demonstrated that a force of 184 kilograms was necessary to avulse a piece of bone at the attachment of a cruciate ligament, and that a force of 614 kilograms was required to fracture an area of the femoral condyle by pressure of the patella against it. It

is probable that in some instances severe trauma may cause the separation of a piece of bone and cartilage, but in the typical case of a young patient with a lesion, often bilateral, in a specific area of the medial femoral condyle and, usually, with no history of severe trauma, this is quite unlikely.

Fairbank, who is one of the strongest advocates of the theory that trauma is the etiological factor, believed that the typical injury in the knee is caused by impingement of the tibial spine against the medial condyle of the femur by internal rotation of the tibia. He had some difficulty in reconciling this with the cases of bilateral involvement and with those of several cases in the same family. These he explained by the assumption of some local anatomical peculiarity. One would have to believe then, that when the elbows or other joints are affected in addition to the knees, the anomalies are present in these joints also. It seems easier to accept that the abnormality is chemical or metabolic.

Those who believe that the pathogenesis of the condition is an area of necrosis in the bone due to occlusion of an end artery include Axhausen [1,2], who found that the fracture was through an area of dead bone which tended not to heal. He offered the improbable explanation that this was caused by a bacterial embolus. Ludloff postulated that the necrosis is due to an injury to the *arteria genu media* where it perforates the posterior capsule. Nussbaum held that this theory was untenable because the *arteria genu media* is not an end artery.

The occurrence of the majority of these lesions in a specific area of the medial femoral condyle does suggest an interruption of the blood supply. However, a study of the circulation in the lower end of the femur fails to support this theory. Rogers and Gladstone made a careful examination of the arterial supply to this region by injection of the arteries with radiopaque material followed by roentgenograms. These preparations demonstrated a rich and apparently adequate arterial network with anastomoses, which would seem to preclude the possibility of an infarct as the result of occlusion of an artery.

In searching for the cause of this particular group of lesions we should, therefore, consider the possibility of some systemic disturbance, such as a metabolic abnormality. Ponseti and associates [21,22,29], impressed by the changes produced in rats on a diet containing aminonitriles in which profound disturbances occurred in the epiphyseal cartilages, leading to avascular necroses and epiphyseal separations, studied a group of cases of Legg-Perthes disease and separation of the upper femoral epiphysis in man. The lesions in the epiphyseal cartilage closely resembled those found in rats. They also found that there was an alteration in the amino acids in the urine of these patients. They called attention to the fact that similar changes in the epiphyseal cartilage of other joints have been found in patients with Legg-Perthes disease and slipped femoral epiphysis.

It may be asked, what has this to do with osteochondritis dissecans? The many instances of bilateral occurrence in the knee joint [10], and the association of lesions in the knee with those in other joints [12], such as the elbow, strongly suggest a systemic defect. Furthermore, osteochondritis of the hip or spine has been found in association with osteochondritis of the knee, as in one of my patients in whom a typical osteochondritis of the patella was followed by osteochondritis of the spine.

Wagoner and Cohn in an excellent summary of the theories about the etiology and pathogenesis of osteochondritis dissecans, cited five case reports (two families) in which similar knee lesions were found in the same family. There were three men in one family—a son, a father, and a paternal uncle. In the other family there were two brothers, in one of whom there was bilateral involvement. These parallel the cases of the three brothers described in this paper and of many other reported instances [4,9,18,24,30,32]. Wagoner and Cohn raised the question whether heredity should not be considered a factor in these cases. It would

seem that they showed it to be so, but they did not speculate about its nature. The improbability that trauma is the sole or even the important agent in these cases, and also that occlusion of a single artery causing an infarct is the cause, make the theory of a systemic metabolic disturbance seem more likely. Further research in this direction would seem worth while.

There is more agreement about the treatment of osteochondritis dissecans than about its etiology. There is no question that when a piece of bone and cartilage has become detached and is loose in a joint it should be removed. Since in a number of instances there has been more than one loose body, some of which may not be demonstrated by roentgenogram, a careful search should be made at operation. If an area of bone has become partially detached and is causing persistent pain and disability it also should be removed.

Gallie and Smillie reported patients in whom they fixed the loose fragment with bone pegs or a screw. Although this resulted in union, it seems very improbable that the articular surface could be restored by this operation. An indented irregular area must remain in the cartilage. The satisfactory results from removal of the fragment lead me to believe that this is preferable, and that efforts to make the separated fragment reunite are not necessary in this particular area of the knee joint.

There are instances, however, in which the necrotic bone has not been completely separated. Some of these joints will heal, probably by gradual substitution and replacement. This was stated by Green and Banks, who reported a series of patients (eighteen joints) who were followed for a sufficient time to demonstrate that they had an excellent result. These patients were treated by immobilization in a plaster cylinder with the knee slightly flexed and without weight-bearing until it was thought that sufficient healing had taken place to permit more activity. Other authors reported cases of spontaneous healing [6,14,15,17,27,31], and several of my patients recovered without operation.

It sometimes is difficult to decide from the roentgenogram whether an area of osteochondritis is completely separated; it would seem best in a child in whose case there is doubt to treat him conservatively until it is proved by repeated disturbances in knee function that the lesion will not heal. If exploration is decided on and it is found that the articular cartilage is intact and the bone not separated, as occurred in several of Green and Banks' patients and in two of my own, it is best to retreat and give the patient an opportunity to heal the lesion himself. It has been my practice in treating these cases conservatively to prohibit running, jumping, and athletic games, but not to immobilize the extremity in plaster. Thus far the results appear to have justified this plan.

SUMMARY

The cases of three brothers with similar lesions of osteochondritis dissecans in the knee joint are reported. The theories of the etiology and pathogenesis of this condition are reviewed and discussed. It is suggested that there are two distinct groups or types of cases. One is the type in which trauma is the cause. The second type, which occurs in children and in which the lesions are often multiple, sometimes is familial and is occasionally associated with osteochondritis in other joints, probably due to some systemic condition. It is further postulated that this may well be a metabolic disturbance.

The treatment of osteochondritis dissecans in the knee is also discussed.

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Anterior Spine Fusion for the Treatment of Tuberculosis of the Spine

The Operative Findings and Results of Treatment in the First One Hundred Cases *

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In 1944 Wilkinson revived an interest in the active surgical intervention in the care of Pott's disease. Since then the popularity of this form of treatment, with its aim to drain the pus and to curette the lesion, has increased year by year. A further report by Wilkinson in 1950 was followed in 1951 by articles by Orell and Kastert, both of whom reported surgery of the lesion in their treatment of the disease. In addition, the latter author wrote that he introduced a rubber catheter into the abscess for local instillation of antibiotics. In the ensuing years, treatment along similar lines was reported by many authors—Cauchoix and associates, Felländer, Kondo and Yamada, Macrae, Mizuno and associates, and Sanchis Olmos.

In 1956 we wrote a preliminary communication on a method of approaching the spine anteriorly, evacuating the abscess with its contents, and fusing the spine by anterior strut and chip transplants. The need for this approach was stimulated by the failures of posterior fusion in some of our patients, many of whom had tuberculous conditions involving four to eight vertebrae and such pronounced kyphosis as to make posterior fusion mechanically unsound.

We should emphasize that the operation can be one of magnitude, particularly in extensive disease, and should not be undertaken lightly, even where good surgical facilities exist. It should not be performed at all where surgical facilities are poor.

We believe that this procedure is indicated as soon as possible after the diagnosis of tuberculosis of the spine for the following reasons:

1. In early disease the operation is much less severe than when the disease has advanced, since the extirpation of the focus is much easier and fusion without deformity is possible.

2. Secondary deformities occur as the disease progresses, impairing function of the lungs and heart. This impairment can be prevented by early operation.

3. The patient's general condition improves dramatically immediately after evacuation of the abscess.

4. The patient can return to work in four to six months.

5. We feel that late recurrence of disease will be less frequent after this procedure.

6. In the thoracic spine, particularly in children, the abscess tends to extend up and down the spine rapidly. Decompression of these abscesses is essential.

7. We know of no certain method of knowing whether a tuberculous lesion of the spine is healed, except by exploration of the area. If the exploration shows that the disease has healed it is perfectly simple to fuse the spine anteriorly for stability.

* Read at the Annual Meeting of the Pan-Pacific Surgical Association, Honolulu, Hawaii, November 18, 1957.

8. Paraplegia did not develop in any patient after operation. We have evidence that the disease can penetrate the dura and affect the cord. (This study will be presented in another paper.)

9. In cases where penetration of the lung is diagnosed, anterior spine fusion is the only method of dealing with the problem.

The main contra-indications to the operation have been lung conditions which would be aggravated by thoracotomy. We have delayed the operation on patients with miliary tuberculosis of the lung and with severe chronic pulmonary tuberculosis in whom the spinal disease was in the thoracic region.

The cases reported here are the first 100 consecutive patients treated by this method; they were admitted to various hospitals but were treated by the same surgical team. The patients were followed carefully after discharge from the hospital, routine roentgenograms being performed every three months. The minimum follow-up has been over two years and the maximum, four years (average, three years).

Two years may be considered too short a time for a follow-up in cases of tuberculosis of the spine; we would agree to this statement with patients treated by previous methods. With this method and within this time we attained healing of the disease by Swett, Bennett, and Street's stringent criterion: "Healing consists of the disappearance of the destructive lesion, a firm bony ankylosis between the remaining portions of the involved vertebrae, and the restoration of a normal consistency to the surrounding bone." All patients were maintained on antituberculosis drugs for from eighteen months to two years. The age incidence of the disease was: up to five years, 40 per cent; from six to ten years, 29 per cent; and from eleven to seventy years, 31 per cent. This younger-age pattern will be readily understood in an area where 94 per cent of the children at the age of fifteen years, and 74.6 per cent of those aged eight years have a positive tuberculin test.

The distribution of the disease was maximum at the tenth thoracic vertebra, the average extent of the involvement being three or four vertebrae. The reason for this pattern of distribution, confirmed by many other authors, is unknown. It is possible that it is connected with the anatomy of the vascular supply of the spinal column, or with the forces and moments about the spine, or both.

OPERATIVE FINDINGS

Involvement of the Lung and the Pleura

In seventy-five of the 100 patients reported with involvement of the thoracic spine, thirty-two patients showed extension of the abscess to involve the pleura or the lung. It is probable that the incidence of this secondary involvement is even higher, for through a unilateral approach we could see, with any certainty, only one pleural cavity and one lung. After evacuation of the abscess in two patients, air bubbles were seen coming from the abscess wall on the opposite side; in one the presence of an abscess within the lung was confirmed at autopsy.

In none of our patients were the contents of the abscess coughed up, although recently in one instance pus was evacuated through the endotracheal tube by the anesthetist. Instances such as these have been reported in the literature when a clinical diagnosis of lung penetration has been made and confirmed at post-mortem examination [37].

We believe that in patients with associated pulmonary and spinal disease, the spine lesion came first. We have seen all grades of pleural and pulmonary involvement associated with moderate or severe spine lesions, but in the course of over 200 operations we have never yet seen moderate to severe pulmonary involvement with early spine abscess which might suggest spread from the lung to the spine.

The course of events in lung penetration by the paravertebral abscess ap-

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Roentgenogram showing a pointed paravertebral abscess on the left side, indicating penetration of the lung.

Fig. 2: Fusiform paravertebral abscess which, at operation, was found to contain tuberculous granulation tissue without frank pus.

Fig. 3: Sequestrated intervertebral disc found lying free in the abscess cavity. This specimen is entirely intervertebral disc.

pears to be as follows: Over the abscess there is localized pleurisy producing adhesions, at first filmy but later thick and vascular. These adhesions limit lung movement and produce marginal lung collapse. This condition has been diagnosed clinically and was discussed by Stevenson. The abscess slowly penetrates the parietal pleura, occasionally bursting into that cavity to produce empyema. More frequently, the abscess slowly penetrates the adjacent layer of collapsed lung, destroying the visceral pleura and gradually producing cavitation, always preceded by collapse and by some fibrosis. Only rarely have we found a communication between the abscess and the bronchus, producing an escape of air. Rarely does fibrosis in the vicinity of the penetration seal off the pulmonary abscess completely from the paravertebral abscess. We have seen this latter process twice, and in both patients the spine lesion was healing.

We have found no evidence of spread of the disease from the lung to the spine, as suggested by both Kaufmann and Burke, or that the thoracic lymphatic duct carries the disease to the vertebral body, as postulated by Fraser.

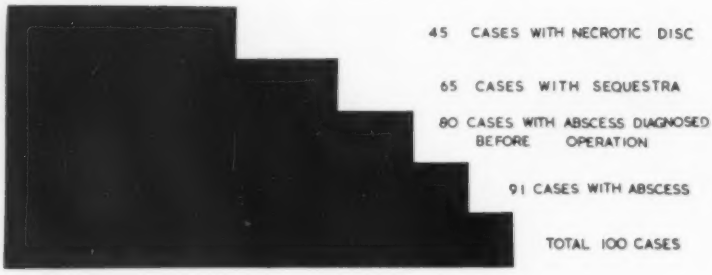
45 CASES WITH NECROTIC DISC
65 CASES WITH SEQUESTRA
80 CASES WITH ABSCESS DIAGNOSED BEFORE OPERATION
91 CASES WITH ABSCESS
TOTAL 100 CASES

CHART I
Operative Findings

In only two of our patients was there appreciable involvement of the para-aortic lymphatic glands and in neither was there caseation within the gland. On several occasions evidence of a paravertebral abscess bursting into the lung was seen on serial roentgenograms, the paravertebral shadow diminishing in size as the pulmonary opacity increased. In some cases the rounded outline of the paravertebral abscess is broken by a sharpness—the point of rupture of the abscess through the wall (Fig. 1). A tuberculous empyema, as described and reported by Brooks in 1942 and Seddon in 1936, was not found in any of the 100 patients reported here, but we have found it subsequently.

Paravertebral Abscess

A paravertebral abscess was diagnosed preoperatively in eighty patients and was found at operation in ninety-one. We should like to stress how difficult it is to diagnose an abscess in disease of the lumbar spine. In most of the psoas abscesses the pus permeates the substance of the muscle itself, instead of collecting between the psoas muscle and the psoas sheath as we had presumed

FIG. 4
Aneurysmal syndrome. The sides of the vertebral bodies are eroded.

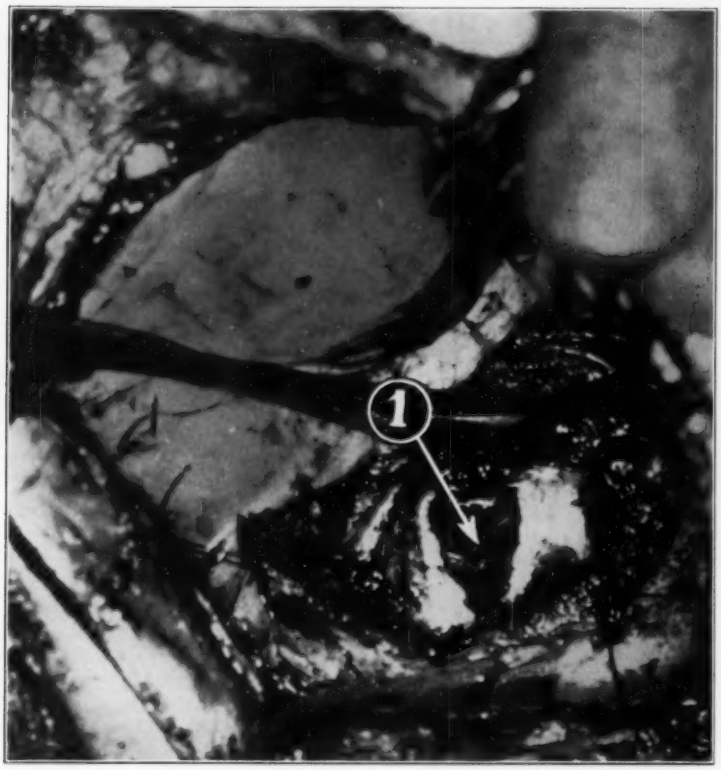

FIG. 5

The aneurysmal syndrome, as seen at operation. Note the erosion of the vertebral bodies at *1* and the relative resistance of the intervertebral disc to disease. Note also that at *1* a complete vertebral body has been destroyed and that disc articulates with disc. It is this persistence of disc which prevents bone fusion.

was the case. In view of the multiple origins of this muscle from the sides of the vertebral body in the lumbar spine, this is not surprising. Nor is it surprising, in some instances, to find that contracture of the psoas muscle and flexion deformity of the hip occur with healing due to the intramuscular fibrosis.

A paravertebral shadow does not always indicate the presence of an abscess. This shadow may be cast by thickened paravertebral tissues without pus formation; this is particularly true if there is a fusiform shadow (Fig. 2).

In ninety-one patients in whom an abscess was found at operation, bone sequestra were found in sixty-five and sequestered discs in forty-five (Chart I). The intervertebral disc is particularly resistant to infection in tuberculosis of the spine, as was pointed out by Compere and Garrison (Fig. 3). The early roentgenographic appearance of a narrowed disc is due to impairment of nutrition to the disc. Although the roentgenogram may not show involvement of the vertebral bodies in these patients, we have invariably found them to be so involved. The aneurysmal syndrome, first described by Ghormley and Bradley, is sometimes seen (Figs. 4 and 5). The peripheral blood supply of the vertebral body comes from the periosteum, as in any long bone; stripping of the periosteum by the abscess removes the blood supply. The avascular bone seems to be rapidly eroding, leaving the vertebral body scalloped at the front and sides while the remaining bone is viable.

The extent of the abscess shadow, in instances where this can be seen,

indicates the extent of the bone disease. Although the vertebral bodies within these limits may appear to be normal on roentgenograms, they are always found to be diseased at operation.

In one patient the paravertebral abscess was found at operation to have dissected along the neurovascular bundles along the lower border of the ribs.

Paraplegia

Thirty-five patients had paraplegia on admission. This is a high incidence when it is compared with the incidence of 11.4 per cent in the series published by Seddon[32] and by Butler, but it is of interest that Cleveland[8] reported an incidence of 29 per cent in one series. In Hong Kong, a serious shortage of hospital beds makes it impossible to treat all patients with tuberculosis of the spine as ward patients, and, consequently, in our series those with paraplegia were given priority. This makes our figure of thirty-five of 100 patients (35 per cent) with paraplegia falsely high. (In Hong Kong, patients with Pott's disease tend to walk and even work while ill; this activity promotes paraplegia.) Of the thirty-five patients, twenty-six made a complete recovery from paraplegia; the average interval of time from onset of symptoms and signs of paraplegia to operation in these patients was 4.8 months. Of the remaining nine patients, six made a

FIG. 6-A

Case 13. Roentgenogram showing concertina collapse of the eighth thoracic vertebra.

FIG. 6-B

FIG. 6-C

Lateral and oblique roentgenograms made seventeen months after anterior spine fusion.

TABLE I

PARAPLEGIA IN 100 CASES OF POTT'S DISEASE

No. of Patients	Average Duration of Paraplegia (*Months*)	Results
26	4.8	Complete recovery
6	29	Partial recovery
1		No recovery
2		Died
Total 35		

partial recovery, one made no recovery, and two died. The average interval of time from onset of symptoms of paraplegia to operation in these nine patients was twenty-nine months (Table I). In our series we noticed a very close correlation between the duration of symptoms before operation and the time taken for patients to recover from paraplegia. If the paraplegia persists for from nine to twelve months, it may become irreversible. Although recovery after twelve months of paraplegia is possible, it is, in our experience, uncommon and never complete.

No part of our work has been so satisfying as the rapid recovery of patients with early paraplegia. The following case abstract illustrates one such patient:

CASE 13. A man, forty years old, was admitted to the hospital with complete paraplegia, including incontinence of six weeks' duration. Roentgenograms (Fig. 6-A) showed a concertina collapse [16] of the eighth thoracic vertebra. The procedure of decompression and anterior spine fusion was performed on January 1, 1956. At operation, it was found that the posterior wall

FIG. 7

Case 221, a boy, six years old, who died shortly after operation. The photograph is an illustration of an anterior decompression of the spine with a strut graft.

of the affected vertebral body had collapsed into the spinal cord, thus causing pressure on the cord.

In three weeks there was complete recovery of function of the spinal cord, with no residual signs of the lesion of the upper motor neurons. At this time the patient started to get up and walk. Two weeks later he left the hospital against our advice, insisting that he had to leave to support his family.

Roentgenograms made seventeen months after operation showed solid fusion (Figs. 6-B and 6-C). At the time of writing the patient was symptom-free and had been working since his discharge from the hospital.

By using the anterior approach we have seen evidence of indentation and compression of the dura and of the cord after incision of the dura, even in patients without signs and symptoms of paraplegia. We feel that granulation tissue surrounding the dura should always be stripped off. If the dura then appears indented, or does not pulsate, or the paraplegia is of long duration, the dura should be opened and the cord itself inspected.

In old healed disease with kyphosis, we found that the granulation tissue over the dura had become fibrous tissue; it was sometimes half a centimeter thick. In the presence of kyphosis the fibrotic dura is kinked, causing pressure on the cord, and, at times, producing a groove in the anterior aspect of the cord.

If the dura does not pulsate, then the cord and its coverings are in contact, and there is no cerebrospinal fluid to transmit the pulsatile impulse. We believe that this indicates meningomyelitis. (The histological evidence for this belief will be submitted in another paper.) In our experience meningomyelitis has been more common in long-standing cases of tuberculosis of the spine. We saw no cases of meningitis result from our procedure—anterior spine fusion—even when the dura was opened.

The spinal cord, like any organ, appears to have a physiological reserve which allows it to withstand considerable pressure and undergo some early changes before clinical symptoms and signs appear. We are satisfied that pressure alone is the cause of the majority of paraplegias in Pott's disease, and are in full agreement with Alexander and Dott that we should be content with nothing short of complete and early relief of pressure if there are any signs of cord involvement.

The anterior approach may be used in those patients in whom paraplegia appears after posterior fusion has been performed. We have only operated on one such patient, a boy who had had a posterior fusion performed in 1950. Severe paraplegia occurred in 1951, and a costotransversectomy was performed, but with little benefit. In 1956 an anterior approach was carried out, and the disease was found to be healed. With the healing, however, a bone ridge had all but transected the cord. Despite this some voluntary active movement was present.

This type of bone ridge has been well described by Griffiths, Seddon, and Roaf; it seems to form during the healing stage of the disease, owing to ossification of the diseased tissue. The forces and moments about the spine tend to retropulse this ossifying mass until it eventually forms a transverse bone ridge which indents the spinal cord and its coverings.

In the patient just discussed the bone ridge was removed through the anterior approach. The cord was exposed above and below the ridge and then the ridge was gently nibbled away with rongeurs. It is essential to be very gentle in this maneuver because the bone ridge is so closely opposed to the spinal cord and its coverings that when the ridge has been removed the spinal cord and its coverings come forward into the space the bone ridge formerly occupied. It may then be necessary to incise the dura as well as to remove the bone ridge. We have named this condition *paraplegia of healing*. Figure 7 shows the cord decompressed anteriorly.

Patients Who Had Been Treated by Posterior Fusion, without Arrest of Disease

Eleven patients had been treated by posterior fusion; five two years previously, five three years previously, and one five years previously. Although we know of no absolute roentgenographic method of telling whether the spine is well fused, all of these fusions appeared to be solid by roentgenographic studies which included anteroposterior, lateral, and oblique views; lateral views in flexion and extension; and, in certain instances, tomograms. The disease was still active in all the patients, despite apparently solid fusion and a minimum of a twelve-month course of antituberculosis drugs. In one patient in this group, a child, slight movement was demonstrated at the site of the lesion at operation despite the fact that on roentgenograms the posterior fusion appeared to be solid.

It would appear that McKee had some justification in writing: "The main conclusion arrived at is that spinal fixation operations performed during the active stage of Pott's disease prevent consolidation between the vertebral bodies at a later stage in the healing process; and that consequently the place of operative aid is solely in the treatment of the end-result, in order to establish a permanent cure of the condition." This is particularly true in the extensive lesions.

Hallock and Jones, on the other hand, claimed that the disease was probably arrested in 74.5 per cent of the 192 patients they operated on during the years from 1931 through 1947. These operations were carried out, on an average, thirty-three months after onset of symptoms. Their criteria of arrested disease were: "Either partial or complete fusion of the vertebral bodies, complete healing of the diseased bone as shown in roentgenograms, subsidence of the abscesses clinically, complete closure of all sinuses, no pain or tenderness over the fusion area, and general well-being of the patient." In describing the roentgenogram of one patient's spine, made thirteen years after initial surgery, they stated: "There had been an increase of 85 degrees in the deformity in spite of a solid spine fusion. The patient was well and able to do heavy labor." Although they did not definitely state that he was included in the "probably arrested" group, they implied it. One feels that they have not been so stringent as Swett, Bennett, and Street in selecting criteria of healing. Henderson, in 1917, reported that: "Neither the Hibbs nor the Albee type of operation for ankylosing the disease area in tuberculosis of the spine is in any sense a radical operation for extirpation of the focus of disease."

Swett, Bennett, and Street studied the relative merits of operative (posterior spine fusion) and non-operative treatment in 350 cases of Pott's disease treated by four different surgeons. This is a very stimulating paper in which the authors come to several conclusions, one of which is: "As determined by the incidence of healing, there is no advantage in the operative treatment over the non-operative." Another conclusion is that the paravertebral abscess plays a dominant role in the course of the disease. It was these fundamental observations that led us to postulate two objectives in the treatment of tuberculosis of the spine:

1. Eradication of the diseased focus and all avascular tissue so that a raw bleeding bed is left, thus giving free access for antituberculosis drugs to the site of the lesion.

2. Early stabilization of the spine. If the spine is made unstable as a result of attaining the first objective, we prefer to stabilize the spine by anterior fusion where the graft is in compression and has an adequate blood supply.

The Aorta

In all patients in whom there was marked kyphosis, the aorta was found to be bent in a U-curve to the left (Fig. 8). The acuteness of the aortic kink

TABLE II

COMPLICATIONS AND DEATHS AFTER ANTERIOR SPINE FUSION

Complications	No. of Patients	Remarks	No. of Deaths	Cause
Postoperative ileus	3	Lumbar involvement in all	1	Pneumonia; bilateral lung involvement
Chest complication	1			
Convulsions	2	Cervical and thoracic involvement; presumably due to streptomycin in contact with theca	1	Excessive intravenous saline solution; pulmonary edema and cardiac failure
Wound sepsis	4	All healed	1	Hepatic failure seven days after cholecystectomy
Keloids, scars	1	Excised		
Slipped grafts	5			
Fractured grafts	7		1	Pneumonia; paraplegia of seven years' duration; very extensive disease from fourth cervical to fifth thoracic vertebra
Increasing angulation	1			
Pulmonary embolism	1	Not fatal		
Cystitis	3	Paraplegia		
Bed sores	3	Paraplegia		

depends on the severity of the kyphosis. Acute angulation did not appear to have any effect on the efficiency of the arterial circulation to the abdominal viscera and to the lower limbs.

Avascular Bone

Increased density of the vertebrae in the diseased area is sometimes seen.

FIG. 8

The aorta is displaced to the left—a hairpin-bend deformity.

FIG. 9-A

FIG. 9-B

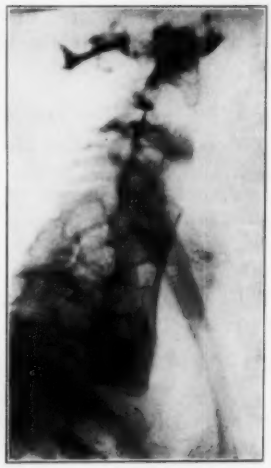

FIG. 9-C

Fig. 9-A: Preoperative lateral roentgenogram, made January 17, 1956, of a patient with tuberculosis of the fourth, fifth, and sixth cervical vertebrae. (Note the trachea pushed forward by the abscess.) Operation in which a homogenous-bone-bank rib was used as the transplant was performed on February 16, 1956.

Fig. 9-B: Nine months after operation.

Fig. 9-C: Roentgenogram made August 2, 1959, three and a half years after operation shows fusion.

This occurs after the disease has been present for many months and is more common in adults than in children. This was described by Cleveland and Bosworth as avascular necrosis. Indeed, at operation the bone is found to be dense and avascular; it is difficult to cut with a chisel, being harder than normal bone, and it does not bleed freely when cut. Microscopic examination of the bone shows that the cancellous spaces are penetrated by granulation tissue; when it is inspected under a strong light with the naked eye, the granulation tissue can be seen to glisten. We feel that it is important to remove this bone at operation if an anterior graft is to be introduced.

COMPLICATIONS

The complications of the operation are listed in Table II. The one chest complication was a postoperative pleural effusion which persisted for six weeks after surgery. In all the other patients the chest was clear at roentgenographic examination made from ten days to three weeks after operation. In no instance was there any evidence of tuberculous infection of the pleura. In five patients the strut transplant slipped to one side or penetrated through the osteoporotic vertebral body at either end; this did not, however, prevent the occurrence of fusion. The rib transplant is not ideal since its end-bearing surface is small. In seven patients one of the strut grafts fractured; this was of little moment, since these grafts are in strong compression and the fractures unite quickly. In all patients healing—as defined by Swett, Bennett, and Street—occurred. Fracture of the graft often occurred in the cervicothoracic and the thoracolumbar regions where there is no splintage from the thoracic cage. In one patient with extensive cervicothoracic disease before the anterior approach was used, posterior fusion was carried out to maintain stability in this very unstable region of the spine. Chips without a strut transplant were used in the patient in whom increasing angulation occurred. We now feel it is useless to use chips alone; a strut transplant is essential if marked kyphotic deformity is to be avoided. Our best results—the occurrence of rapid fusion—were had by those patients in whom the iliac crest, rather than the rib, was used for the transplant. These patients showed fusion by roentgenogram as early as three to six months after

operation. In children under the age of five years the iliac crest is too small to be useful as a strut transplant.

MORTALITY RATE

The mortality rate in the 100 patients reported in this study was 4 per cent. We feel that three of these deaths might well have been prevented.

The causes of death of the four patients were: (1) pulmonary edema and cardiac failure in one patient after excessive amounts of saline solution had been injected intravenously; (2) generalized tuberculosis in a patient who had been quadriplegic for seven years; (3) hepatic failure developing seven days after cholecystectomy and after the patient had recovered from the spine fusion; and (4) postoperative pneumonia in a patient with bilateral pulmonary involvement, death occurring seven days after spine fusion.

POSTOPERATIVE CARE

The patients are placed and cared for on a Lorenz plaster bed with a front and back shell and kept there until their spines are judged, clinically, to have united. To determine fusion we use two tests which we feel are of definite value. The first test depends on the transmission of sound through the transplant. If the transplant has taken, a tap over the spinous process of the vertebral body at one end of the transplant is transmitted to the spinous process of the vertebral body engaged in the other end of the graft. A stethoscope may be used to pick up the sound. It is possible to follow progress of the fusion during the postoperative course, week by week, by the quality of the sound; it comes through unimpaired usually six to twelve weeks after operation. The second test is the spring test. The flat of the hand is placed upon the kyphosis and the weight of the body is transmitted through a straight arm with some force. When this test is used to feel a fused spine, there is no doubt when a spine is springing and is not fused.

When we judge from these two tests that the spine is fairly solid we start mobilization. Gradual mobilization is continued over a period of from six to

FIG. 10-A

FIG. 10-B

Case 73, tuberculosis of the spine involving the twelfth thoracic and first lumbar vertebrae. These preoperative anteroposterior and lateral roentgenograms were made on December 3, 1956.

TABLE III

RESULTS OF TREATMENT IN THE FIRST 100 CASES

Result	No. of Patients
Fused, according to Swett, Bennett, and Street's criteria	93 (one operation)
Fused, according to Swett, Bennett, and Street's criteria	1 (two operations)
Died	4
Non-union	2, but symptom-free

eight weeks, during which time the patients are carefully watched for increasing kyphosis and other signs of activity of the disease. If a long transplant covering many vertebrae has been introduced, the time of immobilization may be much longer. In our patients the average postoperative immobilization was three months and twelve days, and the average stay in the hospital was five months and fourteen days.

RESULTS

All patients were followed for a minimum of two years and a maximum of four; the results are summarized in Table III. A successful result means healing of the disease by solid bone fusion between the vertebral bodies anteriorly (Figs. 10-A through 10-E), as determined by roentgenogram and as already defined.

When we commenced the procedure of anterior spine fusion in 1955 we arranged to carry out the follow-up as a research project. Whilst in the hospital the patients were seen and examined weekly. After they left the hospital all were seen three times a month, at which times roentgenograms were made and the state of the spine assessed. The patients' general health was checked; particular attention was paid to weight, erythrocyte sedimentation rate, and the condition of the lungs, the last in consultation with the tuberculosis specialist. An almoner, or social worker, visited each patient's residence, reported to the

FIG. 10-C

FIG. 10-D

FIG. 10-E

Fig. 10-C: Lateral roentgenogram made after operation in which an autogenous rib was used as the transplant. There is some correction of the kyphosis.

Fig. 10-D: Oblique roentgenogram made October 2, 1957, showing progressing incorporation of the grafts, but healing is not complete.

Fig. 10-E: Anteroposterior roentgenogram made in June 1958. The disease is now healed according to Swett, Bennett, and Street's criteria, although the grafts are not yet fully incorporated.

TABLE IV

REPORTED TREATMENT OF TUBERCULOSIS OF THE SPINE

Author	Year	No. of Patients Followed	Type of Treatment	Results Percentage	Results Grade	Mortality (*Per Cent*)	Length of Follow-up (*Years*)	Comments
Adams	1940	63	Posterior fusion and conservative	60	Recovery	40	5, minimum	Patients all children under 12 yrs. of age
Chandler and Page	1940	39	Posterior fusion	74.36 10.25	Good Poor	15.39	5 to 10	Patients all children under 12 yrs. of age
Cleveland	1940	203	Posterior fusion	55.7 19.2	Excellent Uncertain	25.1	1 to 4	23.6 per cent of patients had spontaneous fusion before operation
Meyerding	1940	396	Posterior fusion	63.34 7.83 3.79 6.31	Good Improved Temporarily improved Not improved	18.73	5, average	Good results: able to work
Swett, Bennett, and Street	1940	140 children	Non-operative	40 43.57 16.43	Healed No healing Questionable	Not given	From 2 to over 20	Children (patients under 13 yrs. of age), no advantage of operative over non-operative treatment; adults (patients over 13 yrs. of age), operative treatment better than non-operative
		62 children	Operative	35.48 45.16 19.36	Healed No healing Questionable	Not given		
		37 adults	Non-operative	18.92 59.46 21.62	Healed No healing Questionable	Not given		
		72 adults	Operative	33.33 38.89 27.78	Healed No healing Questionable	Not given		
Swift	1940	584	Posterior fusion	50 14 8	Excellent Excellent, delayed Failure	28	5 to 24	Of 584 patients, 332 were under 10 yrs. of age; 72 per cent had excellent results
Harris and Coulthard	1942	173	Bone-grafting, 100 patients	46.8 24.6	Disease arrested (bony ankylosis) Not arrested	28.6	1 to 10	73 patients not suitable for surgery
Hallock and Jones	1954	139	Posterior fusion	71.5	Arrest of disease	28.5	11.4, average	Of the 39 patients who died, 4 had arrest of disease before death
Hodgson and Stock	Unreported	52*	Posterior fusion	17.3	Healed	Unknown	4 to 8	Only 25 patients available for follow-up
	Present series	100	Anterior fusion	93	Solid anterior bone fusion	4	2 to 4	Children and adults

*Eleven of the fifty-two patients later had anterior fusion.

orthopaedic surgeon on the home condition, and arranged for help either in financial or in other ways, including extra food if needed. Although we are particularly proud of our follow-up, actually it was rendered easy since there are few places to which the poor patients who suffer from this disease can go from Hong Kong.

There was one case of recurrence. This patient had not returned for follow-up evaluation after discharge from the hospital, and had discontinued the antibiotic treatment. When the patient was ultimately seen, the disease had become reactivated. The lesion was then re-explored anteriorly; the grafts were found to have sequestrated, and a paravertebral abscess had re-formed. The sequestrated grafts were removed, the disease focus was cleaned out, and fresh grafts were introduced. The patient was then kept in the hospital until the grafts took. Now, at the time of writing, the spine is fused and the patient is well. We have included this case with the failures. In two patients whose spines did not fuse, a portion of the intervertebral disc was left behind and pseudarthrosis formed at the level of the remaining disc fragment. Despite the pseudarthrosis, the graft has hypertrophied considerably and the disease appears to have healed in each patient. At the time of writing, both are free from pain and are working regularly.

It is impossible to compare with scientific accuracy the results reported by different workers in their treatment of tuberculosis of the spine. The patients studied were of different races, from different age groups, and had varying degrees of severity of the disease. The criteria used to judge healing were quite different, the most rigid being those adopted by Swett, Bennett, and Street.

Despite these difficulties, we have attempted to compare our results—as judged by the rigid criteria of Swett, Bennett, and Street—with those obtained by others who used either conservative treatment or posterior fusion. As indicated in Table IV our results with anterior fusion would appear to be superior to those obtained with conservative methods or with posterior fusion.

CONCLUSIONS

In the treatment of tuberculosis of the spine evacuation of the contents of the abscess, including the bone sequestra and the sequestrated intervertebral discs, combined with removal of all avascular bone and anterior fusion with a strut graft has, in our hands, given results superior to those obtained by other methods. Although, for the most part, the patients we treated had advanced disease involving many vertebrae, we have obtained our best and most gratifying results in patients with early lesions.

We should like to emphasize the following points:

1. The anterior approach gives a wide access to the disease, which is always more extensive than the roentgenogram would lead one to suppose.

2. The removal of all avascular bone is essential to ensure rapid, sound fusion.

3. Anterior fusion by bone transplantation after a thorough excision of the disease focus is successful in a very high proportion of cases.

4. Anterior fusion by this method has reduced the period of hospitalization from years to months.

5. In agreement with Pott we believe that "fusion of the bodies of the vertebrae is the thing to be aimed at", for a soundly fused spine is unlikely to be the seat of recurrent tuberculosis.

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The Talar-Tilt Angle and the Fibular Collateral Ligaments

A Method for the Determination of Talar Tilt

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In the treatment of ankle sprains it is important to know if sufficient damage to the fibular collateral ligaments has occurred to make the ankle unstable. In order to evaluate the status of the lateral ligaments, it is necessary to establish the normal amount of tilt of the talus which can be produced by supination of the heel in the normal foot.

Previous investigators have reported either no tilt of the talus in the normal ankle in response to stress in the direction of supination [1,23,24,26,31,38,39,40,47,49,50] or a tilt of up to 5 degrees [28]. Occasionally as much as 10 degrees [10] has been reported and tilts of varying amounts (up to 25 degrees) have been recorded in 4 to 5 per cent of ankles studied [4,5]. These discrepancies are particularly significant since tilt of the talus is used as a basic criterion for surgical reconstruction of the injured lateral ankle ligaments [6,14,26,28,34,36,41,49].

There appears to be general agreement that those hypermobile ankles which do reveal a talar tilt present a tilt of equal degree bilaterally [4,5,29]. This, too, is of importance since some surgeons use a difference in talar tilt of the opposite ankle as the criterion for establishing instability of a sprained ankle [10, 17,20,29]. It will be shown that these concepts must be modified.

It is the purpose of this article to describe a standardized technique for the demonstration and measurement of talar tilt, which will permit our results to be equated with those obtained elsewhere by the same method, and to present our results obtained with this method in 100 unselected patients, some with a history of injury and some without. The device illustrated in Figures 1-A and 1-B permits the establishment of equivalent conditions of stress and position for both ankles at the same time.

The need for some standardization of technique was emphasized when one of us measured the maximum inversion stress which he could exert by hand and found this to be forty-five pounds when the test was performed on a hinged model. This finding suggested that wide variations in the amount of stress applied may occur unless some controlled quantitative method of applying the stress is employed. Nilsonne reported one case in which an ankle was tested in supination using a five-kilogram weight, but this appears to be the sole instance in which the force applied was measured. In some studies, supports to hold the foot in inversion have been used, but the amount of stress applied was not recorded, and the ankles were examined separately [12,25].

Comparable positions and equal stress for each ankle are essential for adequate testing.

DEFINITION

The talar-tilt angle is the angle formed by the opposing articular surfaces of the tibia and talus when these surfaces are separated laterally by a supination force applied to the hind part of the foot (Fig. 3).

ANATOMY

Firm supination of the calcaneus at the peritalar joint (that is, the subtalar

FIG. 1-A

The device employed in the determination of talar tilt. Note the wire (arrow) taped to the right leg to serve as an indicator of tibial rotation.

and talonavicular joints) does not produce only tilting of the talus. Other significant changes which accompany this movement will be discussed here.

There are certain features of the anatomy of the foot and ankle which are not included in the anatomical textbooks in common use, although they are of importance.

Calcaneofibular Ligament

This ligament is described in the anatomy textbooks as passing from its attachment on the tip of the lateral malleolus downward and slightly backward to the middle of the lateral surface of the calcaneus (Fig. 3). When the calcaneus is supinated with the foot held at a right angle, this ligament can be felt to become tense beneath the palpating finger. When tensed, the calcaneofibular

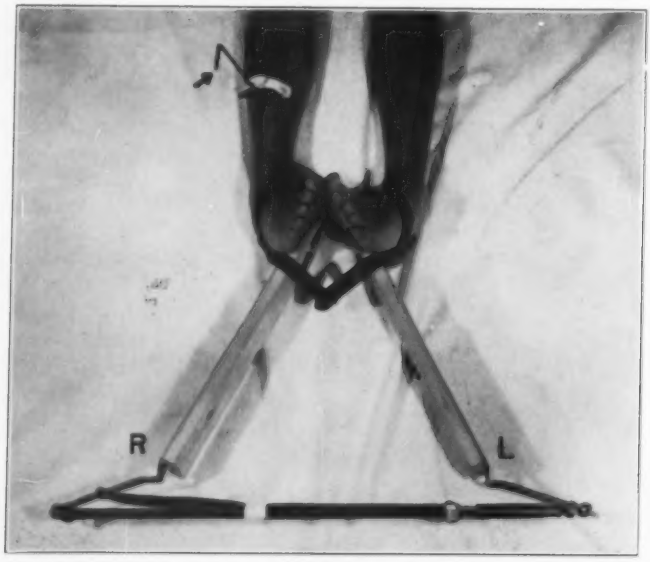

FIG. 1-B

Stress on the ankle in supination has been applied. Note the rotation of the wire indicator (arrow). Compare this figure with Figs. 6-A and 6-B.

ligament can be distinguished from the overlying peroneal tendons, which cross it obliquely, by palpating its posterior border and noting its direction. In the weight-bearing position, the normal calcaneofibular ligament is lax and allows supinatory movement of the calcaneus. It is of interest that mention of this laxity is not made in any of the anatomy textbooks to which we referred [7,11,13,20,33,45]. In fact, statements to the contrary may be found [27,33]. The amount of tension in the ligaments may be influenced by post-mortem changes [32]. This might account for these statements. Sutro reported a group of patients with an unusual degree of hypermobility in many joints, including the ankles, which was associated with periodic joint effusions. He attributed the hypermobility to excessive length of the ligamentous and capsular structures. Bonnin [5] attributed the talar tilt found in his patients to "congenital relaxation of the fibular collateral ligament, particularly the calcaneo-fibular band".

FIG. 1-C
Method in which the feet are strapped to the boards.

The oblique course of this ligament, downward and backward, places it at a mechanical disadvantage for resisting inversion strain. However, this is compensated for by the motion that occurs at the talocalcaneonavicular joint during supination. In complete calcaneal supination, the calcaneofibular ligament no longer runs obliquely downward and backward but tends to assume a vertical direction which improves its mechanical advantage (Figs. 4-A and 4-B). This change in the direction of the ligament is caused by the oblique position of the axis of movement of the talocalcaneonavicular joint.

The peritalar joint behaves as a hinge joint for practical purposes, the foot rotating about an axis which extends from the dorsal and medial aspect of the neck of the talus downward and posteriorly to the inferior and lateral aspect of the tuberosity of the calcaneus [42]. Actually, as described by Manter, the peritalar joint moves like a screw, the calcaneus moving forward with reference to the talus 1.5 millimeters for each 10 degrees of supination. However, this movement is so small that for purposes of this discussion it can be disregarded. The peritalar joint is therefore assumed here to function as a hinge joint. The range of peritalar movement has been described by Biesalski and Mayer (cited by Steindler [47]) as 34 degrees. This is an approximate average of the range reported by others [9,16,47]. This wide range of movement emphasizes how lax the calcaneofibular ligament must be in the normal foot.

The axis of the peritalar joint extends downward and laterally from the neck of the talus, making an angle of 16 degrees with the sagittal plane and an angle of 42 to 45 degrees with the horizontal plane [16,19,32]. (Steindler [46] described the deviation as about 25 degrees from the sagittal plane.)

Since the peritalar structures are hinged proximally to the talus which is held in the ankle mortise, calcaneal movement has, as its corollary, movement of the proximal segment (the talus, tibia, and fibula acting as a unit). As a consequence of the placement of the axis of movement of the peritalar joint, the leg-talus unit rotates externally about its long axis as supination of the calcaneus

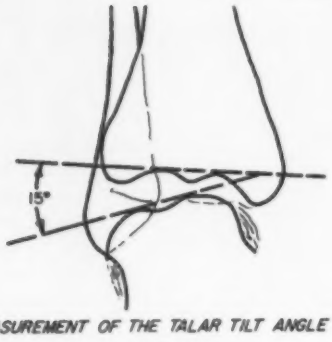

FIG. 2

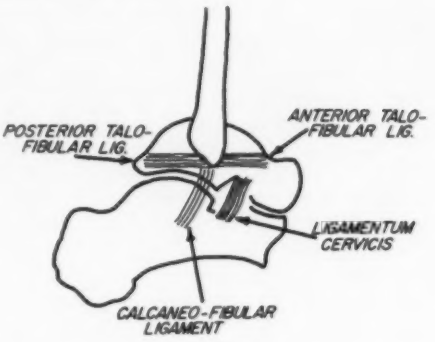

FIG. 3

Fig. 2: Method of measurement of the talar-tilt angle. Compare this figure with Fig. 6-B.
Fig. 3: Lateral view of the ankle and diagrammatic sketch of the ligaments.

occurs, whereas with pronated feet internal rotation of the legs is observed. This movement was referred to by Inman and Close when they noted external rotation of the talus when the subject rises on his toes.

The external-rotation movement of the leg-talus unit during supination carries the fibular insertion of the calcaneofibular ligament posteriorly, or, conversely, supination carries the calcaneal insertion anteriorly. This tends to obliterate the obliquity of the calcaneofibular ligament, with the result that when the ligament is tense, its mechanical advantage has been improved (Figs. 4-A and 4-B).

The amount of laxity of the calcaneofibular ligament found in anatomical specimens may seem to be insignificant. However, when this ligament is observed to become taut during supination, as this movement separates its two points of attachment, it is apparent that there is a significant degree of laxity which has direct bearing on the surgical technique employed in the repair of an unstable ankle. In the Watson-Jones repair, the newly constructed calcaneofibular ligament is directed anteriorly from the fibular malleolus to the base of the fifth

FIG. 4-A

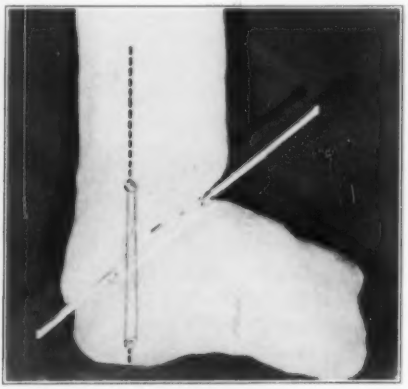

FIG. 4-B

Fig 4-A: Lateral view of the plaster model of the right peritalar joint, with the foot in neutral position. The axis of motion of this combination of joints is represented in the model by a door hinge embedded in the plaster so that its axis of rotation lies in 45 degrees of dorsal and 16 degrees of medial deviation, simulating the normal axis of movement of these joints. The rubber band represents the calcaneofibular ligament, its direction being downward and slightly backward with the foot in neutral position.
Fig. 4-B: The foot has now been supinated. Note that the rubber band (representing the calcaneofibular ligament) now is vertical.

metatarsal, in contrast to the posteriorly directed normal ligament. If the reconstructed ligament is too tight it will prevent supination of the foot or external rotation of the leg on the fixed foot. Watson-Jones apparently recognized the need for some laxity of this reconstructed ligament since he stated that "this part of the ligament should not be unduly tight".

Talofibular Ligaments

The anterior talofibular ligament is described as passing forward and medially from the anterior border of the lateral malleolus to the neck of the talus (Fig. 3). The posterior talofibular ligament passes medially and backward from the fibular malleolus to the posterior process of the talus.

As already described, the mechanical efficiency of the calcaneofibular ligament is influenced favorably by the position of the axis of movement of the peritalar joint.

In a somewhat similar manner the efficiency of the talofibular ligaments is also influenced by movement of the ankle.

With the foot in the normal weight-bearing position the anterior and posterior talofibular ligaments are at a maximum disadvantage for resisting inversion stress since they are placed perpendicular to the line of stress. With the foot in plantar flexion, on the other hand (the position in which most inversion sprains occur), the anterior talofibular ligament is nearly parallel to the line of stress and hence in a position best suited to resist inversion.

In the weight-bearing position it might be anticipated that the horizontally placed talofibular ligaments might give somewhat when the ankle is subjected to inversion stress.

Ligamentum Cervicis

The ligamentum cervicis passes across the sinus tarsi from the lateral aspect of the calcaneus to the talar neck (Fig. 3). No attempt will be made here to describe the innumerable other ligaments and fascial bands about the foot and ankle.

Since this ligament is on the lateral side it must be lax if any peritalar motion is to occur.

J. W. Smith recently studied the sinus tarsi and canalis tarsi and concluded that the cervical ligament limits inversion of the calcaneus * and confirmed the impressions of Barclay Smith, Wood Jones [21,22], and Magnusson. Magnusson concluded that both pronation and supination movements beyond physiological limits were opposed by the strong talocalcaneal interosseous ligament.

The cadaver experiments of Leonard and Pennal indicate that in the equinus position, inversion stress places the anterior talofibular ligament under tension before the calcaneofibular ligament comes under tension, whereas with the foot at 90 degrees the calcaneofibular ligament comes under tension first. (Little attention has been paid here to the posterior talofibular ligament because most authors believe that it is rarely torn [4,15].)

The preceding statements concerning the calcaneofibular ligament are based on observations on the cadaver. They can be readily confirmed in the living ankle. With the foot at 90 degrees, and in the plantigrade position, the calcaneofibular ligament is relaxed, but when the calcaneus is firmly supinated, the calcaneofibular ligament can be felt to become taut beneath the palpating finger. If the foot is plantar flexed and then supinated, the calcaneofibular ligament can no longer be palpated as a taut band.

The work of Leonard, Pennal, Magnusson, and J. W. Smith indicates that in

* After the ligamentum cervicis has been cut, very little force is required to separate the talus and calcaneus [21,43].

both the equinus and the right-angled position of the foot the stress of supination is transferred to the talus by the calcaneus and the ligamentum cervicis of the sinus tarsi. During supination, the calcaneus moves about the peritalar axis until the talocalcaneal ligamentum cervicis becomes tense. Stress is then applied to the talus through this ligament, and the talus begins to tilt, with the following results:

1. If the foot is in equinus position the anterior talofibular ligament is next brought under tension and checks further talar tilt. If this ligament has been torn, as in a sprain, tilting of the talus will continue in the equinus position until the calcaneofibular ligament becomes tense. Should this be torn, there will be marked instability of the talus. Should the posterior talofibular ligament also be torn, gross instability results [29].

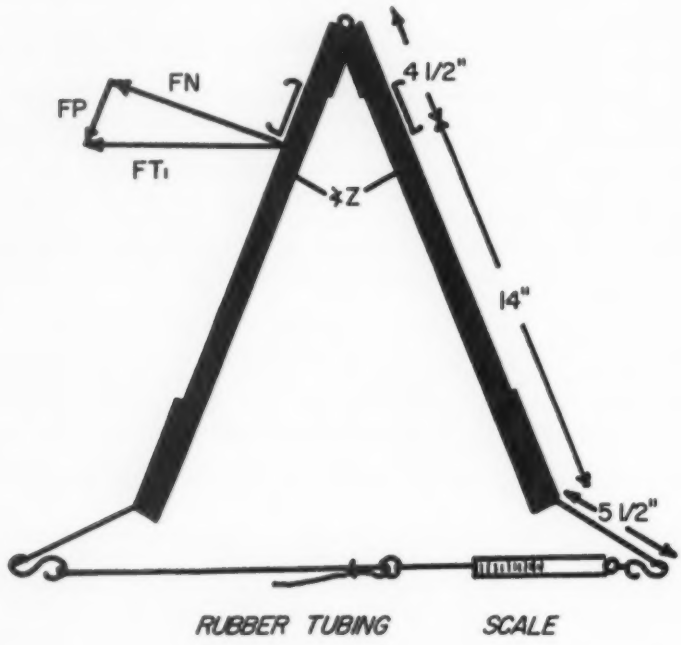

FIG. 5

Drawing and dimensions of the device used to apply stress on the ankle in supination. The basic calculations used to determine the amount of stress applied to the lateral aspect of the ankle are as follows:

Fs = force registered on the scale in pounds;

Z = angle between the boards;

FT_i = total force on each leg;

$$FT_i = \text{FS}\,(2.49 - 0.434 \tan \frac{Z}{2})\,;$$

FT_i may be resolved into the components, FN, the force normal to the board, and FP, the force parallel to it.

$$FN = \text{FT}_1 \times \text{Cos}\ \frac{Z}{2}$$

Sample calculations are as follows:

If FS = 4.0 pounds (that is, the scale registers 4.0 pounds, and Z = 45 degrees, then FN = 8.5 pounds.

If FS = 4.0 pounds, and Z = 30 degrees, then FN = 9.5 pounds.

If FS = 6.0 pounds, and Z = 45 degrees, then FN = 12.6 pounds.

In the series of patients being reported here tensions ranging from four to six pounds on the spring balance were used, which, according to the calculations just given, would mean that the average force applied to the lateral aspects of the ankles studied in this series was in the neighborhood of eleven pounds. Nilsonne, in testing his case, used a weight of 5.0 kilograms, although it is not stated how this force was applied.

2. If the foot is in the 90-degree position when the supination takes place, either the calcaneofibular ligament becomes tense before tension is placed on the talofibular ligaments, with the result that tilting of the talus is prevented, or it becomes tense in a slightly delayed fashion, checking tilting of the talus only after the talofibular ligaments have given somewhat, permitting some talar tilt to take place.

The anterior talofibular ligament as well as the calcaneofibular ligament is probably frequently torn in sprains, as suggested by various investigators [4,41,51]. Wolin and associates were able to relieve persistent symptoms of pain in the sinus tarsi by removing a mass of hyalinized tissue from the region of the anterior talofibular ligament in old sprains. O'Connor employed a somewhat similar procedure in the treatment of a condition which he referred to as the sinus tarsi syndrome (possibly a tear of the ligamentum cervicis). Elmslie described the formation of adhesions in front of the external malleolus and considered them to be a cause of persistent pain.

Tibiofibular Fork or Ankle Mortise

When the ankle is dorsiflexed the broader anterior part of the talus displaces the fibular malleolus two to three millimeters laterally. When the foot is plantar flexed, a little side-to-side movement of the talus in the ankle mortise is permitted [22]. In the dorsiflexed foot the immobile malleoli are in firm contact with the talus and resist talar tilt.

EXTERNAL TIBIAL ROTATION

Figure 3 illustrates the posterior and downward direction of the calcaneofibular ligament as it extends from the fibular malleolus to its attachment on the calcaneus. As the calcaneus supinates on its peritalar hinge there is external "rotation" of the tibia and fibula which move as a unit with the talus, a movement that serves to improve the mechanical efficiency of the calcaneofibular ligament by changing its position (Figs. 4-A and 4-B). As shown in Figure 1-B, a considerable amount of rotation of the leg-talus unit occurs. In 1898 Lovett and Cotton measured the internal rotation of the leg produced by the bearing of weight on the pronated foot. Bonnin [5] reported a case in which he measured the eversion and inversion of the foot with the aid of a pin inserted in the tibia, and found that inversion of the foot caused slight external rotation of the tibia.

As previously indicated, the apparent external rotation of the leg-talus unit associated with supination of the calcaneus is dependent on the placement of the peritalar axis. The range of rotation is not only dependent on the position of the axis but also on the amount of peritalar motion possible.

ANALYSIS OF PERITALAR MOTION

In an effort to clarify the influence of the obliquity of the peritalar axis of motion, models were made with the axis of the hinge joint in various positions. Each model consisted of a long wooden segment representing the leg and talus and a short distal segment representing the foot exclusive of the talus. These were joined by an ordinary door hinge placed:

1. With its axis in the sagittal plane but deviated or rotated 45 degrees from the horizontal in a dorsal direction;

2. With its axis also deviated 45 degrees dorsally and in addition deviated 16 degrees medially from the sagittal plane—the position of the axis of movement of the peritalar joint described by Hicks;

3. With its axis horizontal but deviated 16 degrees medially;

4. With its axis horizontal but deviated 30 degrees medially.

Each model was mounted on a frame (Figs. 7-A and 7-B) with the foot segments "supinated" in approximately equal amounts. The foot segments were

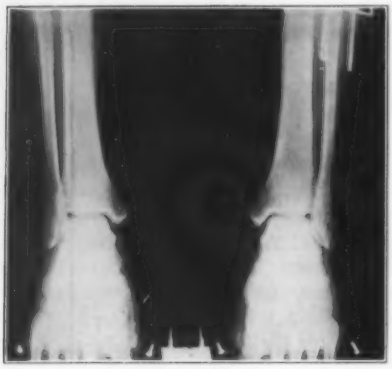

FIG. 6-A

FIG. 6-B

Fig. 6-A: Roentgenograms of the ankles with the device strapped to the feet but with no tension applied.

Fig. 6-B: Roentgenograms of the same ankles with tension applied to the device and the hind part of both feet forced into supination. Note the talar-tilt angles. The patient gave no history of injury to either ankle.

arranged parallel to one another, and the displacement of each proximal segment caused by the various positions of the hinges was noted (Figs. 7-A and 7-B).

Study of the movements of these models revealed that:

1. External rotation of the proximal leg segment occurred only when the hinge axis was deviated from the horizontal plane (Fig. 7-B, models *1* and *2*);

2. Flexion of the leg-talus segment on the foot segment occurred when the hinge axis was deviated from the horizontal plane (Fig. 7-A, model *1*);

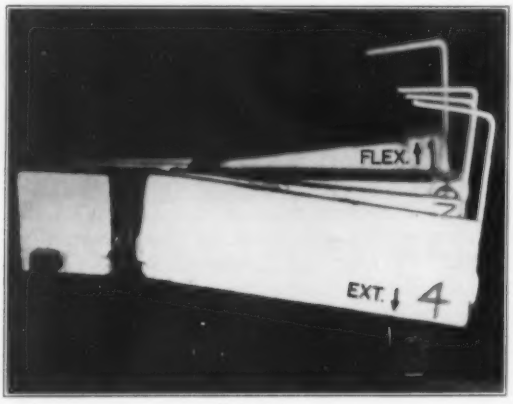

FIG. 7-A

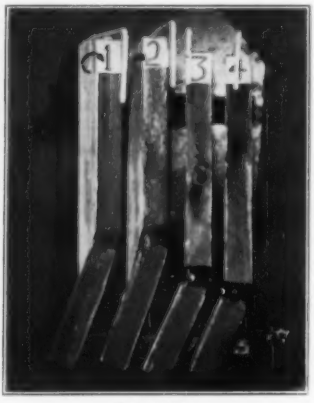

FIG. 7-B

Fig. 7-A: Lateral view of the wooden models with the axes of the simulated peritalar joints in different positions. The short segments of these models, which represent the feet, are held in approximately the same amount of supination and are arranged parallel to each other. This illustration shows the different amounts of flexion and extension of the long (leg) segments of the models which occurred with the same amount of supination of the short (foot) segments but with different positions of the hinge (peritalar) axes.

Fig. 7-B: Anteroposterior views of the models in the same positions.

1. With the hinge axis in the sagittal plane but deviated dorsally 45 degrees supination of the foot caused flexion of the leg on the foot at the peritalar joint combined with rotation of the leg.

2. With the hinge axis deviated 16 degrees medially from the sagittal plane and 45 degrees dorsally from the horizontal plane (the position of the normal peritalar axis as described by Hicks), supination of the foot caused only external rotation of the tibia at the peritalar joint.

3. With the hinge axis in the horizontal plane but deviated medially 16 degrees from the sagittal plane, supination caused extension of the leg on the foot at the peritalar joint.

4. With the hinge axis in the horizontal plane but deviated medially 30 degrees from the sagittal plane, supination caused even more extension of the leg.

3. Extension occurred when the hinge axis was deviated from the sagittal plane (Fig. 7-A, models *3* and *4*);

4. The flexion and extension produced by these two deviations of the hinge axis tended to neutralize each other with the result that when both axis deviations were present (45 degrees of dorsal and 16 degrees of medial deviation) no flexion or extension occurred at the peritalar joint during supination (Fig. 7-B, model *2*).

It is apparent that the external rotation of the leg segment which occurs with supination is due to the oblique position of the axis of motion—more specifically, its deviaton from the horizontal plane.

TECHNIQUE EMPLOYED FOR TALAR-TILT TESTING

The device used (Figs. 1-A through 1-C) is a lever of the second order which consists of two boards, each two and one-half inches wide and eighteen and one-half inches long hinged together as illustrated. The feet are fixed firmly to the boards in similar positions by means of a leather strap as illustrated in Figure 1-C. When strapped in position the feet are parallel to one another with the lateral border of each four and one-half inches from the hinge. The lever arms extend fourteen inches from the lateral borders of the feet to the ends of the boards where they are further extended five and one-half inches by pieces of strap iron which are bent to form angles of 45 degrees with the boards. These dimensions were chosen arbitrarily to provide a compact device, to allow the ankles to fit properly over the x-ray cassette, and to make use of available materials. The outflare of the angled irons provides space for the insertion of the scale. These dimensions may be varied, if so desired, but the calculations made here are based on the measurements detailed. To minimize friction between the levers and the x-ray table, casters were attached to the mid-points of the inferior edge of the wooden levers. These casters also served to raise the lever arms to the level of the cassette.

A scale that would register ten pounds was attached to the distal end of one angled iron, and an elastic tubing was attached to the distal end of the other. The elastic tubing was slipped through the free ring of the scale, and traction was applied by this, thereby inverting the heels up to the limit of the subject's tolerance. The traction registered on the scale was usually found to be between four and six pounds, with a mean of five pounds. The right-angled position of the foot in relation to the leg was chosen for testing to minimize the normal laxity which may result from an equinus position of the foot when the narrower posterior part of the talus is in the ankle mortise. As shown in Figure 5, when the device described is used, five pounds of traction at the scale will result in a force of about eleven pounds at the lateral ankle in the average case.

In order to measure the amount of external rotation of the tibia which accompanies supination of the heel, a metal pointer was rigidly taped to the tibial crest of the right leg (Figs. 1-A and 1-B). When the foot was supinated the amount of external rotation as indicated by the marker was measured with a goniometer. Data on tibial rotation were obtained on eighty-eight of the 100 patients.

MEASUREMENT OF THE TALAR-TILT ANGLE

Perusal of the literature showed that the methods used to measure the talar tilt were not often mentioned. Several investigators [2,29,37] used only one point of reference for the articular surface of the tibia—the tubercle of the anterior articular lip. This method has certain disadvantages. The anterior lip of the tibia is often not clearly visible in the roentgenogram. Furthermore, it lies in a plane anterior to the plane of the tops of the two talar articular eminences which lie in the plane of the middle of the joint. The different distances of these reference points from the x-ray tube will cause some variation in the values

TABLE I

RANGE OF TALAR TILT

	Talar Tilt of 152 Normal Ankles			Talar Tilt of 38 Sprained Ankles		
	Range of Tilt (*Degrees*)	No. of Ankles	Percentage of Total	Range of Tilt (*Degrees*)	No. of Ankles	Percentage of Total
Total group	0 to 23	152	100	0 to 17	38	100
Group with ± 0 degree of tilt	± 0	67	44	± 0	10	26
Group with 3 to 23 degrees	3 to 23	85	56	3 to 17	28	74
Group with over 5 degrees	5 or more	48	32	5 or more	23	60
Group with 10 degrees or more	10 or more	12	7	10 or more	7	18

TABLE II

Age of Patients (*Years*)	Total No. of Ankles	Total No. with Tilt	Per Cent with 3 Degrees or More of Tilt	Range of Tilt (*Degrees*)
20–30	45	31	70	0 to 17
30–40	36	18	50	0 to 12
40–50	42	24	56	0 to 23
50–60	12	9	75	0 to 6
60–70	14	7	50	0 to 7
70–79	3	0	0	0

TABLE III

DEGREES OF TALAR TILT IN OLD HEALED FRACTURES*

Case	Location of Fracture	Amount of Talar Tilt Right (*Degrees*)	Left (*Degrees*)
1	Right lateral malleolus	6	8
2	Right lateral malleolus	0	0
3	Distal part of left fibula	8	11
4	Distal part of the left tibia	4	5
5	Left lateral malleolus with widening of the ankle mortise	0	0
6	Right lateral malleolus with widening of the ankle mortise	0	4
7	Left medial and lateral malleoli and posterior lip of tibia (trimalleolar)	4	4

* One of the eight old healed fractures tested is classified with the sprained ankles because the patient's symptoms appeared to be related to ligamentous injury.

recorded for talar tilt in different patients—the result of unavoidable differences in positioning the x-ray tube relative to the ankle.

Roentgenograms of the ankle joint show that the lower (horizontal) articular surface of the tibia on the anteroposterior view appears as two shallow domelike elevations on either side joined at the mid-line by a slight depression. The subchondral bone of these domelike indentures is easily seen as a fine dense line. This dense line is overlapped by the less sharply defined, inferiorly situated anterior and posterior articular lips of the tibial articular surface. The configuration of the fine dense line can be likened to a shallow 3 lying prone (Figs. 2, 6-A, and 6-B). Occasionally, the subchondral bone forms a straight line. The superior articular surface of the talus shows two corresponding projections which

conform to the contours of the tibial articular surface. The lateral elevation may be slightly higher than the medial, but this does not affect measurement since the talar surface always corresponds. With the aid of a disarticulated ankle and approriately placed lead markers, the position of the prone 3 is easily demonstrated to be in the frontal plane mid-way between the anterior and posterior margins of the tibial articular surface. The talar-tilt angle can therefore be measured with considerable accuracy from lines drawn across the domes of the prone 3 and the corresponding eminences of the talus (Fig. 2). These points of reference are also plainly visible even on oblique views of the ankle.

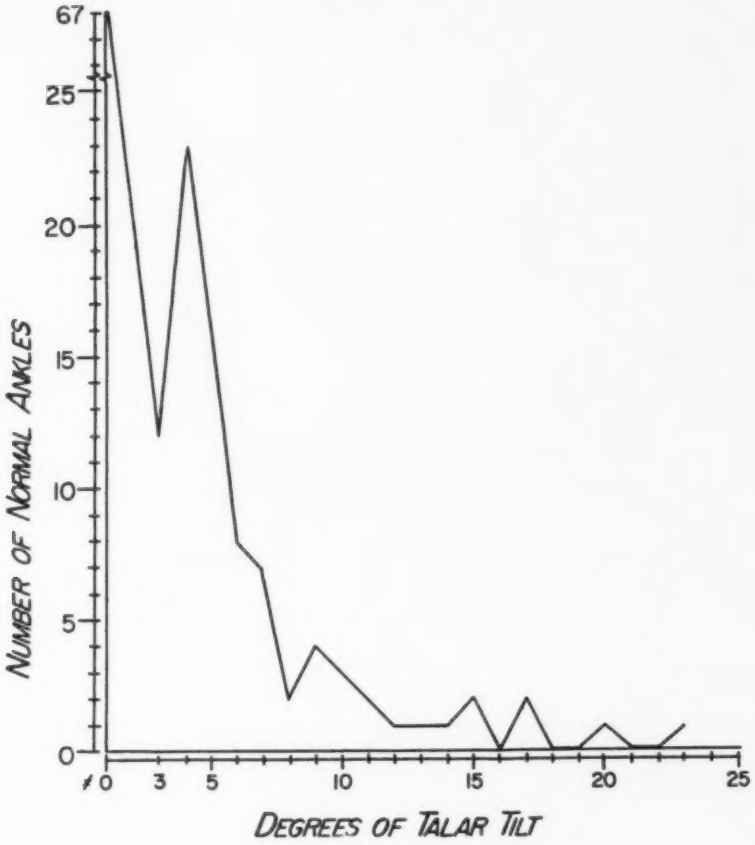

CHART I

RESULTS

Talar Tilt

In recording the results of the measurements of the talar tilt in the 200 ankles * studied, a tilt of less than three degrees was considered as approximately zero (±0 degree).

Normal ankles: The talar-tilt angle was investigated in 152 normal ankles using the technique described, without anesthesia. The results are recorded in

* The 200 ankles were subdivided into two major groups: ankles without a history of trauma (normal, as the term is used here), totaling 152; and ankles with a history of trauma, including thirty-eight sprains, seven fractures, and three with residual peroneal paralysis.

Chart I. Fifty-six per cent of these ankles showed a talar tilt of 3 to 23 degrees. The rest were in the ±0-degree range.

Sprained ankles: The talar-tilt angle was determined in thirty-seven ankles with chronic sprains and one with an acute sprain (Chart II). The acutely sprained ankle with a talar tilt of 11 degrees was the only one examined under anesthesia, which consisted of 1 per cent novocain injected locally in the tender area. Of this group, 74 per cent revealed talar tilt. Table I permits comparison of the findings in the normal and the sprained ankle.

Fractured ankles: The talar-tilt angle was similarly determined in eight patients with old healed fractures of the ankle (Table III). The talar-tilt angles were not abnormal in these ankles even in the two patients with widening of the

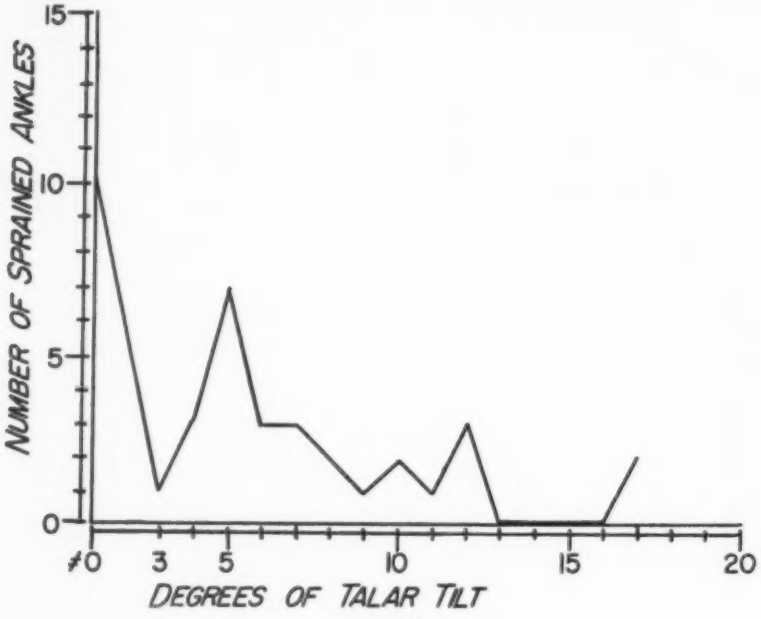

CHART II

ankle mortise. One of these patients with an old fracture was also included in the group of sprains because there was a history of repeated sprains subsequent to the fracture, indicating significant ligamentous injury. Despite this, the tilts in both ankles of this patient were equal and only 5 degrees.

Peroneal paralysis: Three ankles with associated peroneal paralysis were tested and found to show tilts of 5, 8, and 10 degrees, respectively. The ankles with 5 and 8 degrees of tilt were the two ankles of one patient with bilateral paralysis. The 10-degree tilt was present on the paralyzed side of a patient whose ankle on the normal side had a tilt of 20 degrees. Braces had been worn on the paralyzed side since the initial paralytic episode.

Osteochondritis dissecans of the talus: One patient with bilateral symmetrical osteochondritis dissecans of the talus was found to have talar tilts of 4 and 0 degrees.

Right and left normal ankles: Fifty-nine of the subjects studied (118 ankles) had normal ankles on both sides. The differences between the two sides were recorded but are not shown. The designation ±0 degree indicated all subjects in whom the difference between the talar tilt of the two ankles of the same individual was less than 3 degrees. For example, if one ankle measured 7 degrees and the other 5 degrees, the difference was listed as ±0 degree; if one

ankle measured 7 degrees and the other 4 degrees, the difference was then listed as 3 degrees. Twenty-two per cent revealed differences of 3 to 19 degrees. The patient with a difference of 19 degrees was recalled for further study. He reiterated his original statement that he had never injured his ankles.

Sprained ankles as compared with the normal side: Twenty-six subjects had sprained one ankle (twenty-six ankles), permitting comparison with the normal opposite side. Only 27 per cent showed a difference in tilt of 3 to 9 degrees. The remainder showed differences of less than 3 degrees.

Generalized joint hypermobility: There were four patients with generalized hypermobility of joints as manifested by hyperextensibility of the knees, elbows, and hands, as well as third-degree flexible pes planus. None of these patients gave a history of either sprain or fracture of the ankle. The talar tilts in these eight ankles ranged from 4 to 23 degrees.

Third-degree flexible pes planus: There were ten patients (twenty ankles) with severe flat-foot. Two ankles in this group were excluded because there was a history of a sprain, leaving eighteen ankles. Included in this group of patients with pes planus were those with generalized joint hypermobility. Of these eighteen ankles 72 per cent had tilts ranging from 3 to 23 degrees.

Variations with age: In Table II it is noted that the range of tilt appears to decrease after the age of fifty. There were 152 normal ankles in the group.

Negro patients: The talar tilts were determined in seven Negroes, six with no history of trauma and one with a history of bilateral sprain. The range of tilt in the six patients with presumably normal ankles was from 0 to 7 degrees. In the patient with the history of trauma the tilt was 10 degrees on the right and 12 degrees on the left.

Pes cavus: Four patients with pes cavus but no history of trauma to their ankles were studied and found to have talar tilts ranging from 0 to 17 degrees. No appreciable variation in talar-tilt angle was found to be associated with this deformity in this small group. The patient with 0 degree of tilt had severe pes cavus, whereas the one with 17 degrees of tilt had a mild deformity.

Instability (frequent turning over) of the ankle: This symptom was present in twelve of thirty-eight sprained ankles. There were two instances of 0 degree of tilt, seven instances of only 4 to 10 degrees, and three instances of 12 degrees to 17 degrees of tilt. In one case of pes cavus with hypermobile mid-tarsal joints it appeared clinically that the hypermobility of these joints was a major contributing factor to the turning over. It would seem probable that the symptom of frequent turning over may in some cases be related to sprains of the ligamentum cervicis of the talocalcaneal joint [4]. We did not encounter this symptom in the uninjured ankles with a wide range of tilt (23, 20, and 17 degrees). There were no ankles in our series with marked hypermobility and effusion in the joint, as reported by Sutro. It is of interest that the Watson-Jones repair spans the subtalar as well as the ankle joint [49]. Watson-Jones attributed the symptom of turning over to the "formation of adhesions in and around a sprained ligament of ankle". Two of the patients with symptoms of turning over of the ankle had enough trouble to be disturbed by this instability. One was relieved by a high-top shoe with a reinforcing strut. This ankle had a tilt of 9 degrees as compared with the opposite normal side, which tilted 3 degrees. The other patient, already referred to, had pes cavus, hypermobile mid-tarsal joints, and a history of repeated sprains of both ankles. The right ankle tilted 6 degrees, whereas the left side tilted 12 degrees. High-top shoes relieved the symptoms.

Tenderness in the sinus tarsi: Tenderness in the sinus tarsi was found not infrequently in patients with third-degree pes planus, with old ankle fractures, or with history of ankle sprains. The patient with the most persistent complaints of sinus tarsi pain had injured his ankle in 1943 and had had intermittent pain ever since. The talar tilt on the involved side was 5 degrees. We have suggested

surgical exploration of the sinus tarsi, in view of the findings of O'Connor.

Treatment of ankle sprains and residual tilt: The effects of the type of treatment on the amount of residual talar tilt cannot be evaluated without knowing the degree of tilt before and after treatment. The ankle sprains in this series treated without immobilization had an average tilt of 5.4 degrees, whereas those treated by strapping of one week to one month had an average tilt of 5.3 degrees. Six ankles were treated by immobilization in a plaster cast for at least three weeks. These showed an average tilt of 7.2 degrees. No significance can be attributed to these findings. Presumably, the more severely injured ankles were immobilized in plaster casts.

External Rotation of the Leg-Talus Unit during Supination of the Foot

The amount of tibial external rotation accompanying supination of the hind part of the foot was determined in one side in eighty-eight subjects.

The average external rotation for the whole group was 9 degrees, with a range of 0 to 22 degrees. Nine of these eighty-eight patients had third-degree flexible pes planus with an average rotation of 12 degrees (range, 6 to 21 degrees). Four of them had pes cavus, with an average rotation of 9 degrees and a range of 20 degrees. (Subsequent to completion of the study of the series of cases reported here, a sprained unstable ankle was found to have a tilt of 31 degrees. In addition to rotation at the peritalar joint, there was distinct rotation of the foot about the long axis of the tibia at the lax ankle joint.*)

SUMMARY

1. A device has been developed to measure talar tilt in both ankles simultaneously in comparable positions with equal stress on each.

2. An accurate and reproducible method for measuring the talar tilt has been used on 100 male subjects (200 ankles). These included 152 normal ankles, thirty-eight ankles with old or recent sprains, and ten ankles with other abnormalities.

3. Among the normal ankles 56 per cent had talar tilts ranging from 3 to 23 degrees, whereas among the sprained ankles 74 per cent had talar tilts ranging from 3 to 17 degrees.

4. In the fifty-nine patients with both ankles normal, the difference in tilt between the two sides ranged from 3 to 19 degrees in 22 per cent.

5. In eighty-eight extremities the amount of external rotation of the tibia caused by supination of the heel was found to vary from 0 to 22 degrees, with an average of 9 degrees.

6. The influence of the axes of motion of the peritalar joints and of the ankle joint on the function of the fibular collateral ligaments has been reviewed and analyzed.

7. By the use of models it has been shown that the external rotation of the segment composed of the tibia, fibula, and talus, which accompanies supination of the heel, is due to the deviation of the peritalar axis from the horizontal plane as distinct from its deviation from the sagittal plane. Also demonstrated by the models was the influence of each of the directional components of the peritalar axis of motion on peritalar motion.

CONCLUSION

Since there is such wide variation in the normal talar-tilt angle, a talar tilt of less than 23 degrees is not a reliable indication of rupture of the fibular

* Rotation in the ankle joint may occur when the talus tilts sufficiently to release it from the grip of the tibiofibular fork.

The slight rotation that may occur at the ankle joint on dorsiflexion-plantar flexion is not a factor here since the right-angle position of the ankle was employed for testing.

collateral ligament even though the talar tilts in the two ankles of the same individual are different.

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Manifestations of Osgood-Schlatter's Disease in Late Teen Age and Early Adulthood

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The syndrome of pain, swelling, and tenderness over the tibial tuberosity in children at the age of puberty with separation, fragmentation, and sclerosis of the tibial tuberosity and overlying soft-tissue swelling visible in the roentgenogram was first and independently reported as a pathological process by Osgood in the United States and by Schlatter in Germany in 1903. Both believed that trauma to the tibial tuberosity, either directly or indirectly by the pull of the patellar tendon, was the etiological factor and that partial or complete avulsion of the growing tibial tuberosity occurred. Both authors described changes other than acute fracture or acute avulsion of the tibial tuberosity which had been reported previously in the literature.

Since 1903 the exact etiology of Osgood-Schlatter's disease has been questioned. The following causes have been suggested in the literature, according to Aegerter and Kirkpatrick and King: (1) trauma to the tuberosity, with fracture; (2) trauma to the tuberosity, with aseptic necrosis; (3) trauma to the tuberosity, with inflammation; (4) localized infection in the tuberosity; (5) arterial embolism with aseptic necrosis of the tuberosity; (6) rickets; (7) toxic changes; (8) endocrine abnormalities; (9) developmental changes; and (10) traumatic changes in the lower part of the patellar tendon.

Among the roentgenographic examinations of the knee made in the United States Army Hospital, Ryukyu Islands, it was observed that there were wide variations in the roentgenographic appearance of the tibial tuberosity. Because of this observation a study was initiated to clarify the significance of these variations.

MATERIAL

Painful Knees

Two hundred and ninety consecutive roentgenographic examinations were made of patients with painful knees who were referred to the Radiology Department during a six-month period. Each examination included at least a posteroanterior and a lateral roentgenogram of the painful knee and a lateral roentgenogram of the opposite knee for comparison. Each patient was also questioned regarding symptoms, past or present, in both tibial tuberosities. Table I lists the findings in these examinations.

Eighteen (6 per cent) of the 290 patients whose knees were examined were women, but none of their knees demonstrated changes in the tibial tuberosity. Therefore, because of the small number of women, it was decided to limit the study to the 272 consecutive examinations of the men. Most of these 272 men with painful knees, as shown in Chart I, were sixteen years of age or older. They were predominantly United States Army and Marine Corps personnel on active duty. Changes in the tibial tuberosity were found in twenty-six of 272 men (approximately 10 per cent), and twenty-four of these patients presented with acute symptoms referable to their tibial tuberosities.

In order to determine whether these observed changes in the tibial tuberosity were actually abnormal or merely normal variations, a second study was undertaken.

Normal Knees

A total of 470 consecutive male patients who were referred to the Department of Radiology for roentgenographic examinations of regions other than the knee were studied. Postero-anterior and lateral roentgenograms were obtained of both knees. Those patients whose roentgenograms showed changes in their tibial tuberosities similar to those seen in the patients with painful knees were interviewed and examined. Eleven of the 470 patients (approximately 2 per cent) exhibited changes in their tibial tuberosities that corresponded to those found in the patients with painful knees, but all had no symptoms referable to the tuberosity in question at the time of the examination.

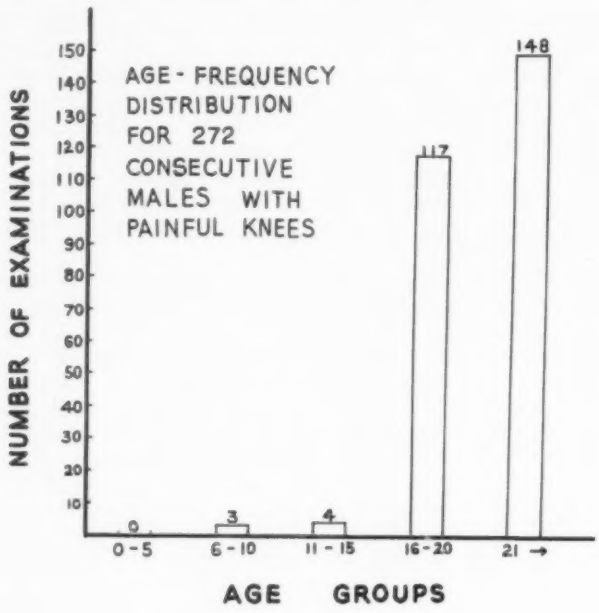

CHART I

As shown in Chart II, the age distribution of these 470 patients is similar to that in the 272 patients with painful knees. The two groups may be considered comparable insofar as age and sex are concerned. Changes in the tibial tuberosity were observed in approximately 10 per cent of the patients with painful knees and in approximately 2 per cent of the patients with normal knees. This higher incidence of changes in the tibial tuberosity in the patients with painful knees suggests that these changes are not normal variations.

FINDINGS

A total of thirty-seven patients exhibited abnormal tibial tuberosities, and seven of these had changes in both knees. As can be seen in Chart III, the patients in this series who had changes in their tibial tuberosities were in an older age group than the patients reported in most studies of Osgood-Schlatter's disease. This age distribution was most probably due to the circumstances of selection present in the military personnel who were studied here. These circumstances offered a unique opportunity to study patients at this age.

For each of the thirty-seven patients with changes in their tibial tuberosities, tracings were made of the lateral roentgenograms of both knees, and the tracings of each pair were superimposed. For each pair of examinations it was

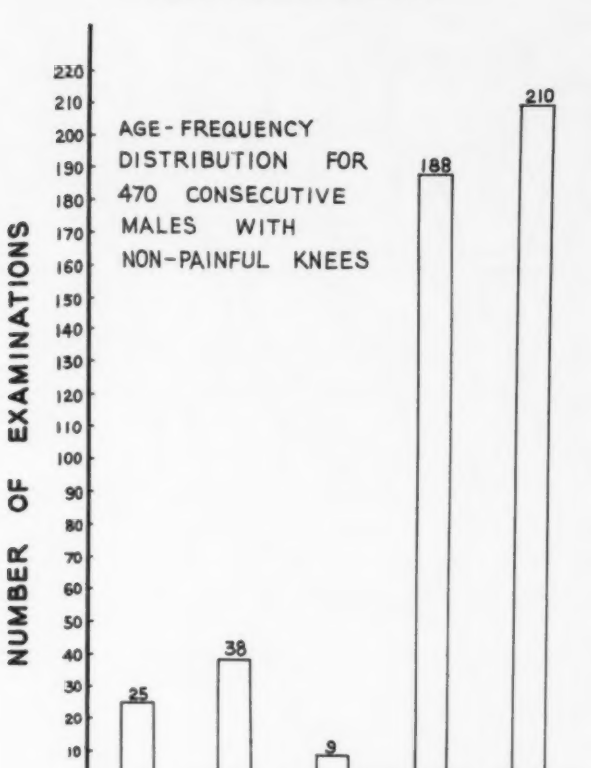

CHART II

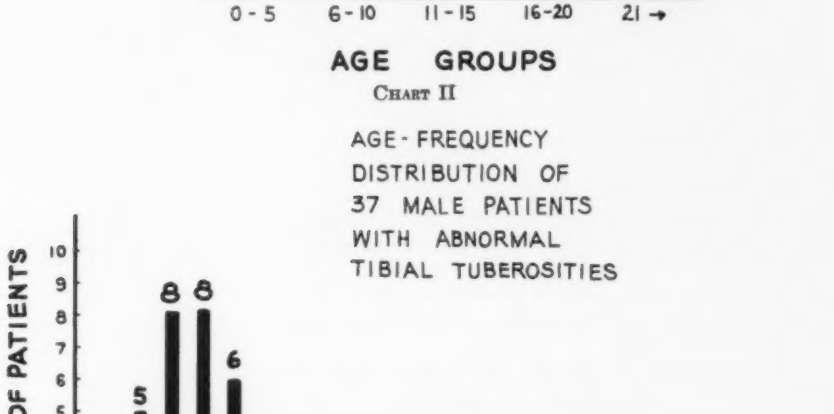

CHART III

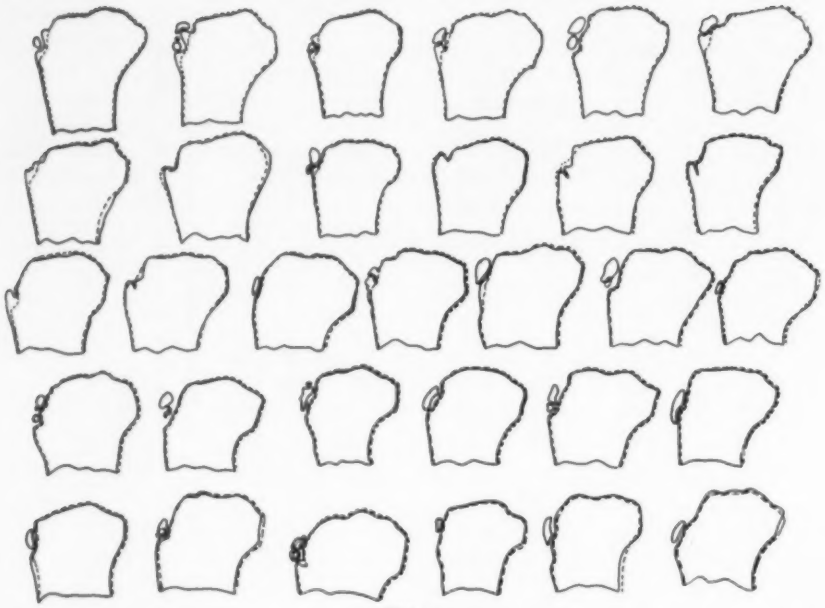

FIG. 1

Superimposed tracings of roentgenograms of both knees of thirty-one men with changes in the tibial tuberosities. The changes are anterior and superior to the normal tuberosity.

easy to superimpose the lateral roentgenograms. With the exception of abnormal changes, a remarkably close correlation was found between the size and configuration of the right and left tibial tuberosities in each patient. Figure 1 shows the superimposed tracings of thirty-one of the patients. In each set of tracings the continuous line represents one knee, and the broken line represents the contralateral knee. Two sets of the tracing show bilateral, prominent, irregular, almost identical tuberosities, which were considered to be definitely abnormal by roentgenographic examination; subsequent history revealed that both patients had had treatment for Osgood-Schlatter's disease at puberty.

Three distinct types of change in the tibial tuberosity were found. These are illustrated in Figures 2-A through 2-C. In type 1 the tibial tuberosity is prominent and irregular. In type 2 it is prominent and irregular, and, in addition, there is a small free particle of bone located anterior and superior to the tuberosity. In type 3 there is also a free bone particle anterior and superior to the tibial tuberosity, but the tuberosity otherwise appears to be normal. In the thirty-seven patients examined, eight had type-1, nine had type-2, and twenty had type-3 changes.

Thirty-one of the thirty-seven patients who showed changes in their tibial tuberosities were questioned with regard to knee symptoms. (The six from whom no histories were obtained were lost to follow-up, owing to rapid troop movement.) Twenty-eight of the thirty-one men interviewed had at some time experienced definite acute symptoms of tenderness and swelling about the tibial tuberosity, and twenty-one of these twenty-eight recalled that the onset of these symptoms occurred at or shortly after puberty. Ten of the twenty-one men associated the onset of symptoms with trauma. Seven of the twenty-eight men had had the onset of their symptoms one year or less before being examined for this study, and all recalled trauma as an initiating event. This trauma was usually not violent, and several men noted symptoms after kneeling for many hours at target practice. All seven of these patients were in the group with

TABLE I

DIAGNOSTIC FINDINGS IN 290 KNEES

Diagnosis	Frequency
No abnormality demonstrated	220
Abnormal tibial tuberosity	26
Loose bodies in knee joint	11
Effusion of undetermined etiology	5
Osteochondritis dissecans (undisplaced bone fragments)	4
Traumatic arthritis	3
Bipartite patella	2
Fractured patella, acute	2
Bone cyst in the tibia	2
Prepatellar bursitis	2
Irregularity of the inferior pole of the patella (Sinding-Larsen)	2
Soft-tissue calcification outside the knee joint	2
New bone adjacent to medial femoral epicondyle (Pellegrini-Stieda disease)	2
Changes in the patella secondary to old trauma	1
Dislocation of the patella	1
Fracture of the lower part of the femur	1
Cellulitis	1
Calcification in a cruciate ligament	1
Cyst in the lower part of the femur	1
Fracture of the anterior tibial spine	1

painful knees. An additional seventeen patients from the group with painful knees recalled one or more exacerbations of symptoms which occurred after onset at or shortly after puberty. Two patients in the group with painful knees, each showing type-3 change, and two patients in the group with normal knees, each showing type-1 change, had no symptoms referable to the tibial tuberosity at the time of the study, but all four of these men recalled that they had had symptoms at puberty.

FIG. 2-A

FIG. 2-B

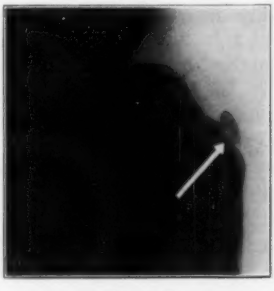

FIG. 2-C

Figs. 2-A through 2-C: Roentgenograms demonstrating the types of changes found as late manifestations of Osgood-Schlatter's disease.

Fig. 2-A: Type-1 change. Fig. 2-B: Type-2 change. Fig. 2-C: Type-3 change.

Approximately one-quarter of the patients presenting with acute symptoms had soft-tissue swelling about the involved tibial tuberosity, visible on the roentgenogram, combined with type-2 or type-3 changes in their tuberosities. The remaining patients with acute symptoms showed no definite evidence of soft-tissue swelling on the lateral roentgenograms, but all showed type-2 or type-3 changes. Type-1 changes were found only in patients who were not currently having acute symptoms but who did recall having had symptoms about the time of puberty.

Five of the patients with acute symptoms, all showing type-3 changes, were not relieved by conservative treatment consisting in immobilization for at least

six to eight weeks in a plaster cylinder with the knee in extension. In these five patients the particle of bone was excised. In each instance the small ossicle was found to be embedded in the posterior aspect of the patellar tendon anterior and superior to the tibial tuberosity. The tuberosity itself appeared normal, and the patellar tendon inserted in its normal position on the tuberosity. Histological examination of the removed ossicles revealed viable cancellous bone surrounded by cartilage with no evidence of necrosis or inflammation.

DISCUSSION

It is generally agreed that trauma is the cause of Osgood-Schlatter's disease, but there is no agreement as to the nature of the lesion which results from the trauma. In their original papers Osgood and Schlatter stated that trauma caused partial or complete avulsion of the tibial tuberosity. Since that time Uhry and Cole have presented findings which support the concept of Osgood and Schlatter. More recently, Fels and Hughes suggested that trauma produces changes in the lower end of the patellar tendon which result in the formation of new bone in the damaged portion of the tendon. It is interesting to note that Codman, in his discussion of Osgood's paper at the time that it was presented, stated that Osgood had presented acceptable evidence that partial avulsion or damage to the tibial tuberosity itself was the initial lesion but Codman also reviewed his former opinion that the changes in the tibial tuberosity were caused by trauma to the lower end of the patellar tendon or to its insertion with resultant periostitis and subsequent new-bone formation in that area. Today, the pendulum of thought is again swinging to the original view of Codman.

Our observations on these patients with Osgood-Schlatter's disease in a group older than those previously reported reveal several findings of interest. Acute symptoms of pain and swelling about the tibial tuberosity, associated with abnormal roentgenographic findings, were observed in seven patients over eighteen years of age who recalled no previous similar symptoms. Comparison of the normal with the abnormal knee in all instances revealed that the changes were located anterior and superior to the tuberosity. Twenty of the thirty-seven patients had single or multiple, apparently viable, ossicles located in the lower patellar tendon anterior and superior to the normal tuberosity.

It is probable that actual avulsion of the tibial tuberosity does occur in a small number of cases. LaZerte and Rapp recently presented convincing histological evidence of avulsion in at least one case. Their conclusion that all Osgood-Schlatter lesions are the result of avulsion, however, does not seem warranted by the findings in their remaining material. Although it is conceivable that actual fracture or avulsion of the tibial tuberosity may occasionally occur, our findings seem to support the view that the Osgood-Schlatter lesion in the majority of cases is secondary to traumatic changes in the lower end of the patellar tendon with secondary new-bone formation.

SUMMARY

Abnormalities in the tibial tuberosity were observed in the roentgenograms of thirty-seven male patients on active duty in the military service. These patients were older than those usually described as having the Osgood-Schlatter lesion. Three types of change in the tibial tuberosity could be distinguished in the roentgenograms, and these changes are thought to be definite manifestations of this lesion. The presence of soft-tissue swelling anterior to the tibial tuberosity suggests acute symptoms, whereas a prominent, irregular tuberosity suggests inactive disease. No other correlation between the roentgenographic appearance of the tuberosity and the clinical status of the patient could be made in this age group. Our studies indicate that the etiology of the Osgood-Schlatter lesion in the majority of patients is injury to the lower end of the patellar tendon with resulting new-bone formation.

(References on page 369)

Fracture Separation of the Lower Humeral Epiphysis

Report of a Case

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Fracture separation of the lower humeral epiphysis is a rare and unique injury of the elbow related only to trauma in the young child. Owing to lack of ossification of the epiphysis, the younger the person the more acuity is required by the physician to make the diagnosis. There is a paucity of literature on this subject, and many texts do not mention this injury when discussing supracondylar fractures or injuries around the elbow in children. Ashhurst reported seven cases in 1910, and in 1955 Smith mentioned separation of the lower humeral epiphysis in his book. The diagnosis must always be considered in children who suffer injury to their elbow with a loss of the normal landmarks. To understand this problem more fully a review of the epiphyses of the distal humerus should be made.

The lower portion of the humeral epiphysis of a child resembles that of the adult except that it is composed entirely of cartilage which does not

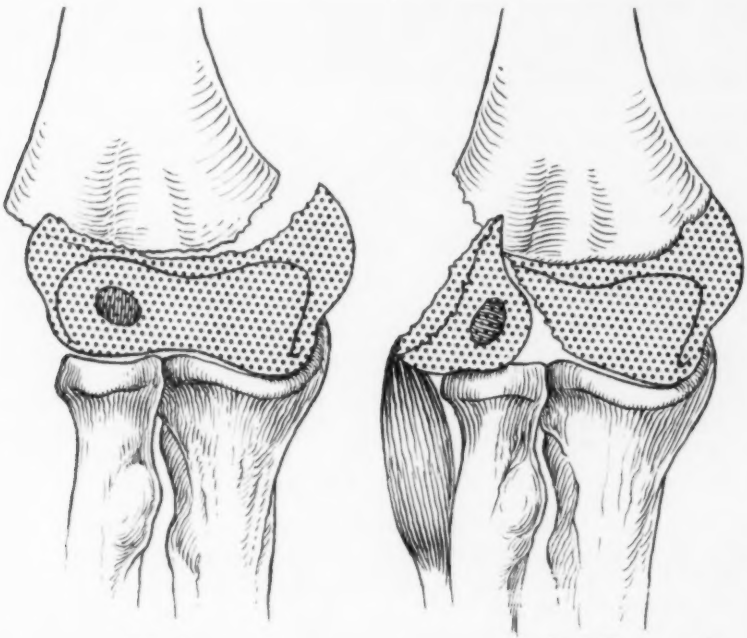

Fig. 1-A

Fig. 1-B

Fig. 1-A: Drawing of lower humerus revealing a fracture separation of the distal epiphysis. Note the relationship of the capitellar ossification center to the radius.

Fig. 1-B: Illustration of a fracture of the lateral condyle of the humerus with rotation of the fragment.

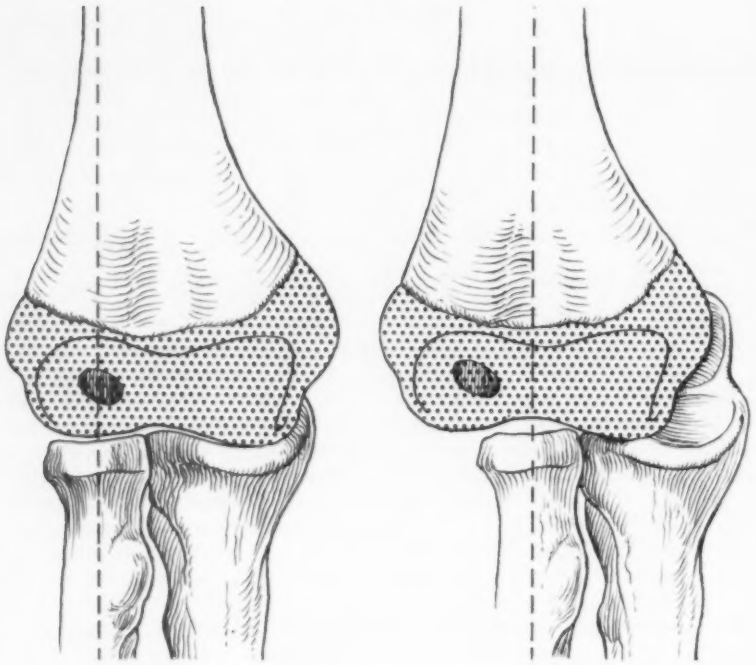

FIG. 2-A FIG. 2-B

Fig. 2-A: Drawing of normal elbow illustrating the relationship of the capitellar ossification center to a line passing up the shaft of the radius. This line passes through the capitellum.
Fig. 2-B: Drawing of a dislocated elbow revealing the displacement of the line drawn through the radius and the capitellar ossification center, illustrating the difference between a dislocation and a fracture separation of the entire epiphysis.

show in a roentgenogram. The capitellar ossification center is the first to appear at the elbow. At about the age of two years it appears, and unites with the shaft at sixteen years of age. The ossification center of the medial epicondyle appears on roentgenograms at five years, followed by that of the radial head between five to seven years of age. The trochlear and olecranon ossification centers appear at ten years of age, and all the epiphyses are united by the eighteenth year. It is advisable, therefore, to obtain comparable roentgenograms of the opposite elbow in all children with injuries around the elbow to aid in the diagnosis. This is a valuable procedure and is recommended strongly as a routine measure.

In fracture separation of the lower humeral epiphysis, the fracture line passes through the junction of the cartilaginous epiphysis and the metaphysis (Fig. 1-A). The entire epiphysis may be displaced posteriorly, medially, or laterally, depending on the mechanics of the injury.

DIFFERENTIAL DIAGNOSIS

It may at times be difficult to differentiate this injury from a fracture of the lateral condyle, but in the latter injury the fragment is often rotated 180 degrees by the pull of the extensor conjoined tendon, and the capitellar ossification center is displaced (Fig. 1-B). This does not occur in separation of the epiphysis since there is no loose fragment to rotate. It is important to differentiate between these two types of injury because a displaced lateral condyle usually must be replaced by open reduction and internal fixation to prevent non-union and to restore a suitable joint surface, whereas a separa-

FIG. 3-A

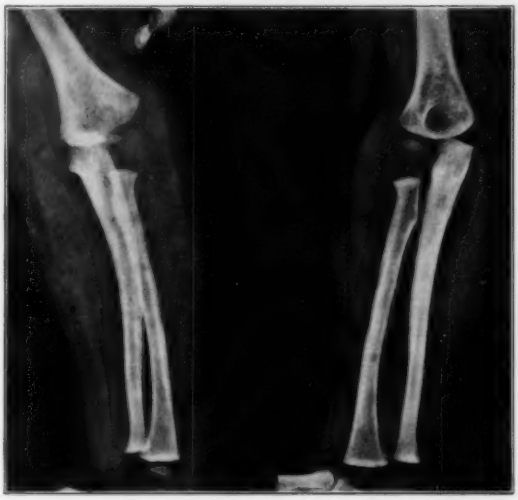

FIG. 3-B

Fig. 3-A: D.R. Photograph revealing the gross deformity of the carrying angle fourteen months after injury.

Fig. 3-B: Roentgenograms made March 9, 1958, of both elbows, for purposes of comparison. In children, a roentgenogram of the normal elbow is of great value so that the epiphyseal lines may not be mistaken for fractures. The roentgenogram at the left of the illustration shows the fracture separation of the epiphysis with medial displacement. Note the relationship of the capitellum and the radius.

tion of the epiphysis can easily be reduced by closed reduction in a manner similar to that used for a supracondylar fracture.

The injury can also be confused with a dislocation of the elbow because the epiphysis, when displaced, carries the radius and ulna with it producing, at first glance, the appearance of a dislocated elbow. The key to the diagnosis is the relationship of the capitellar epiphysis or ossification center, which is displaced, with the ulna and radius, therefore maintaining its normal relationship with these bones. Normally, a line drawn up the shaft of the radius will pass through the capitellum (Fig. 2-A), whereas in a dislocation a line through the radius does not pass through the capitellum, indicating a disruption of the joint (Fig. 2-B).

CASE REPORT

D.R., a child, two years old, was injured in March 1958, when he fell on his right arm while playing. He was seen by an osteopath, who made a roentgenogram of the patient's elbows (Fig. 3-B). The right elbow was then placed in a cast for six weeks. When the cast was removed, the child was noted to have a marked gunstock deformity of this elbow with limitation of motion. The patient was first seen in August 1958 at the University of California Medical Center where a review of roentgenograms made at this time revealed a fracture separation of the lower humeral epiphysis with medial displacement. The range of motion in this arm was: extension, 150 degrees; flexion, 55 degrees; pronation, 0 to 90; and supination, 0 to 90 degrees. On the left the carrying angle of the elbow was 10 degrees of cubitus valgus. On the right there was a gunstock deformity with 20 degrees of cubitus varus. When the patient was re-examined in June 1959, fourteen months after the injury, his range of motion was: extension, 165 degrees; flexion, 60 degrees; pronation, 0 to 75 degrees; and supination, 0 to 90 degrees. He had a 15-degree gunstock deformity. Function, however, was good (Fig. 3-A).

TREATMENT

This injury should be treated by closed methods. The medial or lateral displacement should be corrected first, as in the reduction of a supracondylar fracture, by manipulation of the fragment while traction is maintained

on the forearm. When this displacement has been corrected the elbow may be flexed in order to lock the fragment into place. A posterior molded splint is applied for fixation and maintained for three weeks. Gentle manipulation in reduction is important to prevent further damage to the epiphysis and subsequent growth disturbance. It is wise to admit these patients to the hospital for careful check on the radial pulse for the first twenty-four hours. If there is marked swelling of the elbow when it is first seen, and, if the pulse disappears on flexion of the elbow, the method of choice would be skeletal overhead traction with a Kirschner wire in the olecranon or Dunlop's traction. Open reduction of this fracture is not indicated.

CONCLUSIONS

Again, the importance of differentiating this injury from fracture of the lateral condyle must be emphasized. The latter disrupts the joint surface when displacement occurs and usually must be treated by open reduction in order to obtain a satisfactory result. On the other hand, a fracture separation of the epiphysis will respond very well to closed management, since the joint surface is intact.

The displacement of the radius and ulna along with the capitellar ossification center is pathognomonic of this injury. The patient's family should be warned of the possibility of growth disturbance and changes in the carrying angle of the elbow due to the injury to the epiphyseal cartilage.

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Congenital Pseudarthrosis of the Clavicle

Report of a Case with Resection and Bone-Grafting

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Congenital pseudarthrosis of the clavicle is an extremely rare entity. The literature contains many articles on the treatment of pseudarthrosis of the clavicle [1,3,6], but a careful search revealed only two reported cases of true congenital pseudarthrosis of this bone [2,5]. Moore, in his excellent article, mentions the occurrence of congenital pseudarthrosis in a number of bones, including the clavicle, but does not specifically describe treatment of a case involving the clavicle. The following case is reported as a definite instance of congenital pseudarthrosis

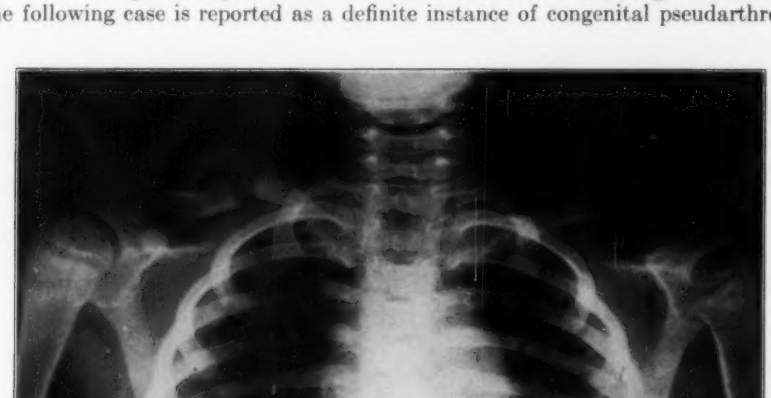

FIG. 1

Roentgenogram showing pseudarthrosis of the right clavicle at time of first examination.

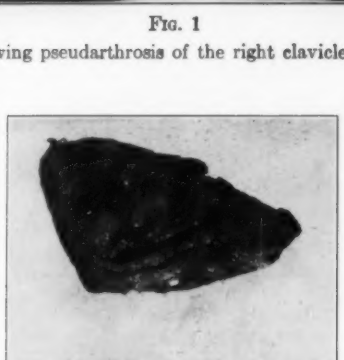

FIG. 2

Photograph of resected specimen. Note the false joint and the break in continuity of the periosteum at the site of the pseudarthrosis (lower part of photograph).

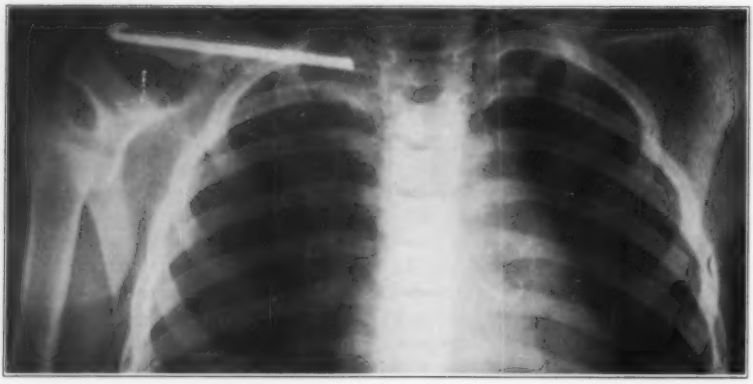

FIG. 3

Roentgenogram of shoulder, made after surgery, with an intramedullary pin in the clavicle.

FIG. 4

Roentgenogram of shoulder twenty-six months after surgery and after removal of the intramedullary pin.

of the clavicle which was repaired successfully by resection of the pseudarthrosis, intramedullary fixation, and bone-grafting.

L. V., a white boy, five years old, was first seen on June 27, 1957, because of pain of two months' duration in the right shoulder. The parents said they had been told that the child had a "congenital type of fracture of the right clavicle" at birth and had been advised that no specific treatment was indicated at that time. The child had developed normally and had no complaints referable to his shoulder until two months prior to the initial examination. The obstetrician who delivered the child said that the delivery was uncomplicated, and no traction had been applied to either arm during delivery. The obstetrician particularly remembers that a non-tender enlargement was present at birth in the middle third of the clavicle, and that he was impressed at the time that this mass was different from that usually seen with traumatic birth fracture. The pediatrician who followed the child until the age of three years has since died, but the patient's hospital record was reviewed. A notation in the record made by the pediatrician states that "infant has congenital fracture of right clavicle, not painful to palpation or movements of shoulder". There had been no roentgenogram of the clavicle prior to the one made by us in June 1957. The office records of the deceased pediatrician were not available for review. The local family physician reported that the child had been seen by him on several occasions for minor complaints and that he was aware of the lesion in the child's shoulder, but his records did not show any reference to the enlargement of the right clavicle until early May 1957. At that time both parents stated the "lump", which had always been present in the middle third of the right clavicle had, in their opinion, begun to increase

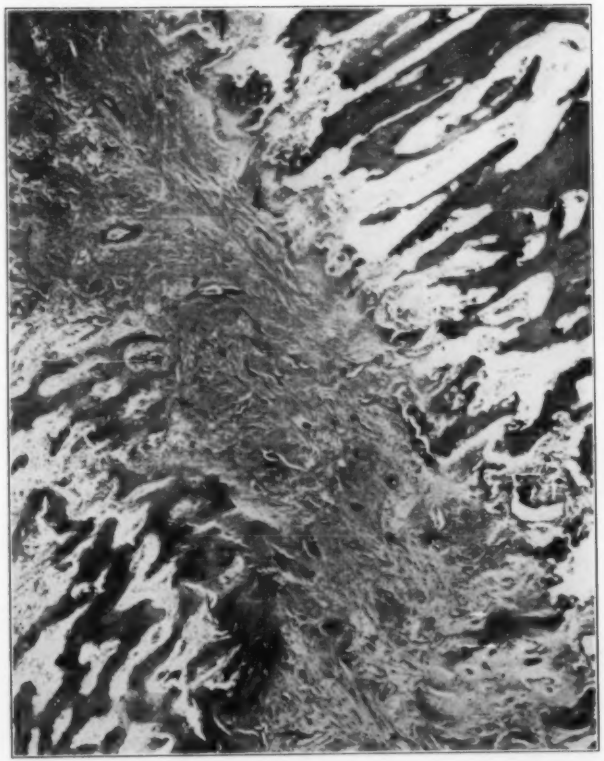

FIG. 5

Photomicrograph (× 25) of the lesion, showing central island of dense fibrous tissue between mature areas of bone.

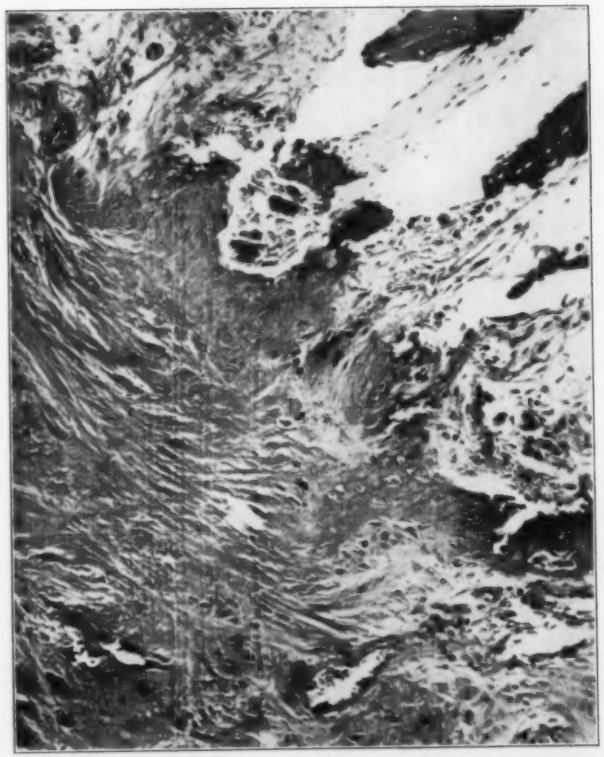

FIG. 6

Higher-power view of the same central island of fibrous tissue (× 100).

in size. The boy had also begun to complain of pain with excessive use of the arm, such as climbing or throwing a ball.

A roentgenogram (Fig. 1) made on June 27, 1957, revealed an area of apparent pseudarthrosis in the middle third of the right clavicle. Clinically, there was definite motion present over this area with very slight discomfort on forceful palpation. Because of development of clinical symptoms referable to this lesion, operation was advised. At operation the periosteum of both the medial and distal fragments extended to the edge of the area of pseudarthrosis, but it was not continuous across the apparent false joint. There was no continuity of the periosteum between the two fragments, as would be seen in non-union of a traumatic fracture. The area of pseudarthrosis was resected completely; the resected segment was 2.4 by 1.5 inches (Fig. 2). The gap remaining between the proximal and distal fragments of the clavicle was filled with small fragments of a homogenous-bone graft (rib), and firm internal fixation was accomplished with a small intramedullary pin (Fig. 3). The right upper extremity was immobilized in a Velpeau bandage for a period of four weeks and then discontinued. Subsequent roentgenograms showed good union of the bone graft and in April 1958 the intramedullary pin was removed. The patient was last seen in September 1959. At this time he had full range of motion of his shoulder with no clinical symptoms referable to the clavicle. Roentgenograms (Fig. 4) showed good union of the area of pseudarthrosis, with a suggestion of recanalization of the medullary canal.

DISCUSSION

When this patient was first seen by one of us (E.B.C.) the lesion was thought to represent either congenital pseudarthrosis, neurofibromatous defect in the bone, or, possibly, non-union of a birth fracture. The absence of *café au lait* spots on the patient suggested that this was not a localized neurofibroma. The absence of tapering of the bone ends, a common finding in congenital pseudarthrosis, was disturbing but it was surmised that since the clavicle is not subjected to weight-bearing, tapering of the bone ends may not occur in this bone (in contrast to the tibia). The initial absence of pain and our inability to account for the development of pain during the short period prior to our first examination were disturbing. Non-union of a birth fracture was not considered seriously since it was felt that non-union of a fracture of the clavicle in a newborn infant would be highly unlikely. It was also our opinion that the original roentgenographic findings and subsequent operative findings were not characteristic of non-union of a traumatic fracture.

Admittedly, this lesion does not show all the criteria normally seen in congenital pseudarthrosis of the tibia, but in the absence of any previously reported accurate description of congenital pseudarthrosis of the clavicle, we feel that this case presents sufficient clinical, roentgenographic, and pathological evidence to substantiate the diagnosis of congenital pseudarthrosis. The pathological sections (Figs. 5 and 6) of the specimen were reported as showing: "Dense fibrous proliferation with no evidence of osteoblastic or chondroblastic activity seen. The dense fibrous proliferation is not continuous between the two bone fragments. The fibroblasts are mature cells with somewhat pyknotic nuclei. There is no evidence on repeated sections of this lesion representing a neurofibroma. After reviewing the roentgenograms and gross specimen and consideration of pathological sections, we believe this lesion represents a true pseudarthrosis."

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Spinal Involvement in Gout

A CASE REPORT WITH AUTOPSY

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Gout as a disease is found described in the earliest medical writings, and the presence of deposits of urates in the joints has been known since Wollaston's description of 1797. A considerable amount of literature concerning this metabolic disturbance has accumulated over the years. This is well reviewed by Talbott in his excellent monograph [9], and some of the surgical aspects of the disease have been discussed in recent articles contributed to this Journal [5,10].

Although one is taught to consider gout in the differential diagnosis of low-back pain, little reference to low-back pain in association with gout can be found in the literature on this disease. In fact, with the occasional exception of the cervical spine which is more commonly implicated, the authors of the standard textbooks either ignore the spine as a site of clinical complaint in gout or summarily

FIG. 1

Facets of the fifth lumbar vertebra, showing widespread urate deposition in the articular cartilage.

say that it is rarely involved [1,2,3,8,9,11]. A recent report of an extensive autopsy on a patient with severe involvement mentions that urate deposits were found in the vertebral bodies and discs, but makes no mention of the posterior intervertebral joints and their capsules [4]. Another report of an autopsy on a patient with similar involvement mentions only vertebral lipping in the thoracic spine and makes no comment concerning the lumbar spine or the other spinal joints [6].

The following autopsy report is therefore felt to be worthy of record.

S.C., a Negro, fifty-one years old, was a shipping clerk. On admission he complained of dizzy spells and of pain and some swelling in both knees, the left long finger, and the right second toe of one week's duration. For three years he had had intermittent attacks of pain and swelling in these swollen joints, and had been treated with salicylates and cortisone by several physicians who had made a diagnosis of rheumatoid arthritis. He did not complain of

back pain, and subsequent discussion with his relatives revealed that to the best of their knowledge he had never had backache. Renal failure was the principal cause of admission—his first to this hospital.

Physical examination revealed slight cardiac enlargement and a blood pressure of 190 systolic, 110 diastolic. There were tenderness and slight swelling of the joints previously mentioned.

The hemoglobin was 9.6 grams per 100 milliliters, the sedimentation rate was slightly raised, the blood urea nitrogen was 69 milligrams per 100 milliliters, and the serum electrolytes were normal. Serological tests for rheumatoid arthritis showed: C-reactive protein, 2+; latex fixation test, 0; antistreptolysin-0 test, 12 Todd units; latex slide test, weakly reactive; and euglobulin latex, negative. The serum uric acid was not determined, and no roentgenograms of the skeleton were made.

After admission the patient's renal failure became rapidly more marked, the blood urea nitrogen level rising to 172 milligrams per 100 milliliters, and the serum potassium level to 9.2 milliequivalents per liter. He died twenty-five days after admission.

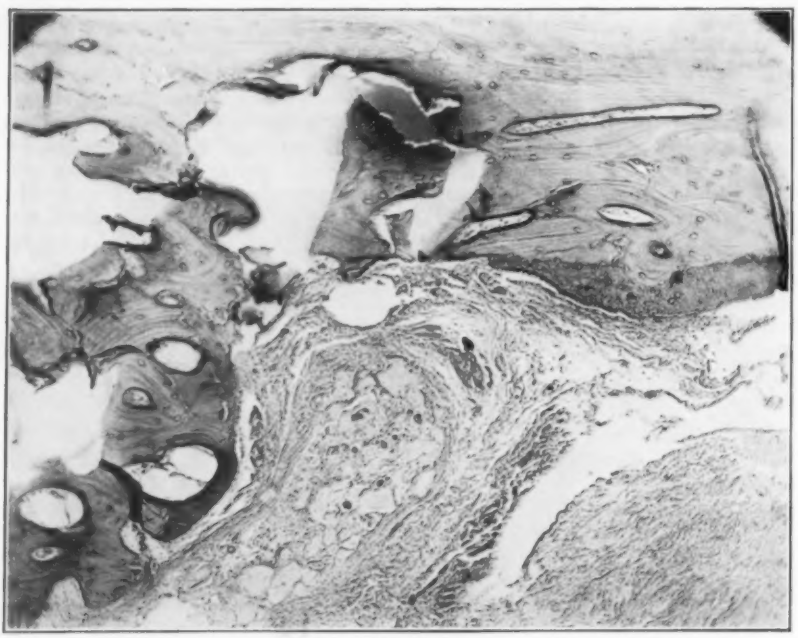

FIG. 2

Microscopic section showing a gouty granuloma at the junction of the capsule and articular cartilage.

Autopsy revealed arteriosclerotic heart disease with moderate cardiac enlargement and considerable narrowing of the lumina of the coronary arteries, mild bilateral bronchopneumonia, severe bilateral nephrosclerosis, moderate benign prostatic enlargement, and bladder distention. The spine from the tip of the coccyx to the fifth thoracic vertebra was removed by a modification of a procedure previously reported by one of us[7]. The left knee was also removed. Dissection of the spine showed no abnormality of the posterior articular processes, the costovertebral joints, or the intervertebral discs from the fifth thoracic vertebra to the third lumbar vertebra other than some slight degeneration of the articular cartilage. However, in the posterior articulations between the fourth and fifth lumbar vertebrae and to a greater extent in the posterior joints between the fifth lumbar and first sacral vertebrae there were extensive deposits of urates in the capsules and ligaments and over the articular cartilage. No urate deposition was found in the intervertebral discs. The urate crystals did not invade deeply into the articular cartilage, but firm wiping would not separate them from the cartilage.

The left knee showed the same widespread deposition of urate crystals over the articular cartilage and synovial membrane, and several sizable deposits were found in the ligaments and capsules. The menisci were coated on both sides with urate crystals.

Microscopic sections of the articular processes of the fifth lumbar vertebra were made. Typical gouty granulomata containing crystalline deposits and foreign-body giant cells were

found. These occurred maximally at the junction of the capsule with the articular cartilage but were also spread widely throughout the hyaline cartilage. In the areas of cartilage involved by the urate deposits, degeneration was found, manifested by widespread fibrillation and some fissuring of the cartilage in the immediate neighborhood of each deposit. In some places the fissuring extended to the subchondral bone. There was nothing found in the microscopic sections of the kidney to indicate that the renal failure was related to gout, and no urate deposits were found in the non-skeletal tissues.

DISCUSSION

The frequency with which gout is diagnosed depends on the "gout-mindedness" of the examiner. The necessity for determining the serum uric acid in the presence of joint pain and swelling of unknown etiology has repeatedly been stressed and need not be further belabored.

The fact that this patient did not complain of back pain is probably not of great significance. It is well known that joint degeneration in the spine, as shown by roentgenogram, may appear long before backache develops. Similarly, gouty deposits are not necessarily correlated with pain. What would seem to be significant in this case is that the deposits were confined to the spinal joints in which degenerative changes most commonly occur—the fourth and fifth lumbar. This small piece of evidence would suggest that the degeneration of the articular cartilage so frequently found in relation to gouty deposits and usually attributed to their presence may in point of fact be a predisposing factor leading to formation of the gouty deposits rather than resulting from them.

The frequency with which gout leads to complaints of back pain is not great, according to the literature. However, this autopsy shows that gout does involve the spinal joints in the low-back region and supports the contention that this disease should be included in the differential diagnosis of low-back pain. It would be of interest if other workers who have the opportunity to perform autopsies on patients with gout would examine the posterior intervertebral joints of the spine.

NOTE: We wish to thank Dr. H. L. Jaffe, Director of Laboratories, for permission to publish this case, Dr. Howard Cooper for assistance with the autopsy, and Miss Mia Benninga for assistance with the manuscript.

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Growth of the Vineyards*

BY HAROLD A. SOFIELD, M.D., OAK PARK, ILLINOIS

Fellow Members of the Academy, Guests, and Ladies: One cannot stand in this position without experiencing mixed emotions. Perhaps the strongest emotion at the moment is one of deep humility, humility born of inadequacy and responsibility. To be selected to guide the helm of this, the largest honorary society of orthopaedic surgeons in the world, now numbering almost three thousand, is a sobering and maturing event. If one did not enter upon this position at the start of the year with humility I am sure that by the time he stood before you to address you at year's end, he would have changed and by then known his humble sense of responsibility. The second emotion is a strong feeling of pride. Not pride in position, but pride in the organization. The Academy is a young, vigorous, rapidly growing society. Each of its twenty-six years has seen great strides in membership and in its sphere of influence. It has no quotas or numerical restrictions on membership, which tend to exclude the younger men, and it has no geographical boundaries. Let us hope that it will always extend a welcoming hand to all good orthopaedic surgeons, regardless of age, place of abode, language, or customs.

A vigorous, growing organization must look ahead. It should not be too concerned with living in the past or in trying to observe outmoded traditions. The rapidity with which our world is changing makes forward vision not only desirable, but absolutely necessary for survival. We are living in an age where fantasy becomes reality and where the impossible dreams of last night are the factual stepping stones of this morning. Time and space shrink so rapidly that the schedules printed at the start of the month are obsolete at month's end. Three months ago we flew from Los Angeles to Chicago in three and one-half hours. Recently we left Miami at nine o'clock in the morning and were in Chicago two and one-half hours later. Even more startling was our travel time last month when returning from a side trip following attendance at the Congress of the Latin American Society of Orthopaedic Surgery and Traumatology in Santiago, Chile. On the morning of December ninth we were in the old Inca capital city of Cuzco, high in the Andes mountains of Peru, almost eleven thousand feet above sea level. We had spent two days and two nights there and in the surrounding territory. On the morning of December ninth, after breakfast, I visited the interesting old market and walked about the city. It was an entirely different world, filled with unfamiliar Indian peoples speaking strange languages and observing unfamiliar customs. My home seemed far, far away both in time and space, yet we were having lunch in Chicago the next noon after a good shower bath and change of attire. It was difficult for us to adjust to the fact that the previous morning we had been eating in Cuzco and, following that, had spent ten hours touring Lima. The world has suddenly become small, and mythical far-away peoples whom we never expected to see except in colored photographs in The National Geographic Magazine are now our next-door neighbors. It is incumbent upon us to develop means of communication with these folks next door. We must try to understand their ideas, develop a method of language exchange, know their philosophies and cultures, and draw closer to them in a common community. They must do the same with us, for only by mutual understanding will respect and friendship be fostered. This is not a one-way street of advantages, for we will gain in knowledge and experience to the

* Presidential Address read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1960.

same extent that we share our ideas and developments with others. Even as we talk here today, the drawing boards of our major aircraft companies have on them blueprints of commercial airplanes that will fly not six hundred miles per hour, as do our present jet planes, but twenty-five hundred miles per hour. In a very few years these "strange" folks who only recently became our next-door neighbors will be sharing rooms in the same house with us. The time for adjusting ourselves to new circumstances is short. Isolation, even if desirable, which it is not, is as dead a possibility as the tomb of the Pharaohs of a thousand years ago. Governments in all their functions, including economic and military concepts, are struggling frantically to keep pace with the changing world. World leaders are flying in hours from one world capital to another, vying with each other to cement friendly relations with the nations that now are all in one small package in time and space. Businesses no longer know national boundaries but even moderate sized enterprises have factories and offices on the shores of the seven seas. The appointment of a military leader in Pakistan a few years ago might have rated a small paragraph in an insignificant portion of our newspaper but now it becomes a headline of considerable importance. Even the impact of a change of policy in Hong Kong is felt all over the United States.

Hard-headed, practical business men have rolled with the punch of this rapidly changing world and have adjusted their methods not only for survival but for expansion of their enterprises. Governments faced with the grave responsibilities of existing in a world where life or death may hang on the events of a single moment are using all their facilities to keep pace with the international situations. Science in general is trading knowledge and gaining more understanding by constant interchange of men between countries and there have been more international meetings in the past five years than were held in the previous fifty years. It is an exciting, challenging era which demands action and offers vast new areas of information and knowledge to the alert and progressive elements of society, but by the same token of speed, it forces a rapid decline in importance to those who fail to keep up with the increased tempo of knowledge and activities.

What has the art and science of medicine done to meet the challenge of this new world? What, in particular, has orthopaedic surgery done to adjust itself to the rapidly changing events? What has the Academy done to assure its members of a continuing leadership role in our specialty, and what must we do now and in the future to take our proper place in the world picture we must now envision? No longer can we tranquilize ourselves with the therapy of geographical isolation and superior technical equipment. We either step forward in a group at the vanguard of world medical education and cooperation or we relegate ourselves to a position of secondary importance and inferior knowledge.

A look at the picture of medicine in the nations of the world today is of interest. The freer interchange of medical knowledge, brought about by rapid travel, increased exchange of medical documents, visiting lecturers and guest speakers, exchange professorships, earphone translations of foreign languages, and the increasing merging of nationalities in joint scientific meetings is creating an atmosphere of respect and friendship between peoples of different racial backgrounds and different cultures. The greatest of all common denominators binds together practitioners of healing—that denominator is, of course, the patient. Modern medical men in all countries do not strive to have secret cures, secret medicines, or patented techniques. If ever there is a field of endeavor which should know no jealousies and which should strive for the common good, it is the field of medicine. This recent increase in the dissemination of medical knowledge has led, and continues to lead, to improved medical schools all over the world, improved medical education after graduation, and improved care of the patient. Somewhat contrariwise, the situation in Russia is an example of the results of isolation. The doctors of Russia, unable because of political reasons

to have free access to the rapidly expanding storehouse of medical knowledge of the rest of the world, have as an entity been unable to keep pace with the great strides of advancement. Medical journals, even at the best, are considerably behind progressive work. Very frequently, doctors who will speak on research work at meetings will hesitate many years before publishing results for fear that the passage of time may negate their previous conclusions. As a result of isolation, Russia has developed a few outstanding scientists in the medical field. These men and women are perhaps the equal of top medical scientists anywhere in the world. The sad truth, however, is that the general level of medical work in the Soviet Union is far below the average of the rest of the leading nations of the world. A few stars do not make a heaven. Unfortunately for the medical profession of Russia, and through no fault of their own, the political powers who direct the destinies of the Soviet Union have downgraded the medical profession until it no longer attracts the number of top-flight men that previously gave their life interests to the healing art. Now we find a very high percentage of women in the medical field in Russia because good men are urged to go into other fields. Such are the fruits of isolation. For every year that medical knowledge is retarded in a country it seems to take many years to recover the lost time.

American medicine is somewhat at the crossroads. We must go forward or we will go backward. During and following World War II we enjoyed stability and economic advantages beyond those of almost all other nations. Our medical research laboratories were, and are, better financed than those of other countries. Prosperity and natural advantages made us smug and content with our lot and not anxious to spend much time inquiring into the work of less economically favored peoples. Then the fact that our prosperity depended on the prosperity of the rest of the world was forced home to us. Other nations through hard work and help became self-sufficient and their standard of living improved to measures comparable to the more favored nations. The jolt of the Russian space exploits brought us up with a start. Perhaps we were not the omnipotent power that we had led ourselves to believe. Now we are hectically dashing about trying to follow the lead into space but with small indication that we are apt to catch up for a long time. Economically, our export-import balance is not so favorable as might be desired. More worrisome is the depleted store of our gold reserves which on demand would leave us a bankrupt nation. In other words, we not only desire to be friends with other nations; we must have other nations as our friends in order that we may exist.

The same is true in the field of medicine. Complacency must be replaced by active leadership in forming alliances with medical societies in other countries so that more complete interchange of medical knowledge may result. In Europe such alliances in medical societies are commonplace and are increasing all the time. Witness the recent meeting in May of 1959 of the combined British, French, and Belgian Orthopaedic Associations. Have we ever had a combined meeting of the Canadian, Latin American, and United States associations? The answer is "no". Should we? The answer definitely is "yes".

Let us examine our Academy in its relationship with modern world progress. Have we ever entered into or sponsored any combined meeting with any other orthopaedic organization either in this country or away from our national borders? No. The Academy is the natural counterpart of the British Orthopaedic Association, the Canadian Orthopaedic Association, and the Latin American Society of Orthopaedic Surgery and Traumatology. All these organizations admit to membership all well qualified orthopaedists. There are no restrictions on the number of members in the societies and all are truly national in scope and large in numbers relative to their orthopaedic populations. It is high time that the Academy assumed its natural obligations and began cooperating with other organizations in bringing to its members the advantages of progressive ideas fostered beyond our national limits.

Although a young society should spend most of its time looking forward, a brief glance backward might put the forward views in better perspective.

The birth of the Academy was not accompanied by a difficult labor. Those of us who were on the scene at the time well remember the relatively smooth organization of the embryonic society. The smoothness of organization was a tribute to the genius of the American Orthopaedic Association leaders who saw the need of an inclusive organization, truly national in scope, which could grow with the increment of numbers of younger orthopaedists. My professor, my teacher, and, I am proud to say, my friend, Dr. Edwin Ryerson, was the organizational President in 1933. Almost concurrent with the birth of the Academy was the organization of the American Board of Orthopaedic Surgery in 1934. Certainly nothing in the history of American orthopaedics has exerted so great a force for the establishment of high standards of ethical and professional care of patients as has the Board, and nothing exists that can preserve high standards as can the Board. Only recently, bending to pressure, the Board has finally taken on some international aspects which have been hailed enthusiastically abroad. When, early in the life of the Academy, Board Certification was made a requisite for consideration for membership, a standard was established which not only gave the Academy a measuring stick for professional ability but it established Board Certification as a recognized, desirable, and almost necessary qualification. In common with all policing and examining authorities, the Board is the whipping boy of our specialty and will always remain so. Criticism of all Boards of all specialties is so natural that in 1952 an article entitled "Secretary of the Board" appeared in the Journal of the American Medical Association. The paper started with a quotation from Gilbert and Sullivan's *Pirates of Penzance or The Slave to Duty.*

"Ah, when constabulary duty's to be done (to be done)
A policeman's lot is not a happy one."

It appeared to the writer that the Board secretary was similar to a constable but lower in the social scale; perhaps similar to an umpire except he has much longer hours and gets no pay. Permit me to state that in my opinion there is no more difficult position in orthopaedics than service on the Board. One must expect criticism and not credit, but if a deep feeling of doing a worth-while job is any reward for service, one gets it from that position. However, again quoting the article just mentioned, the Board must not feel as naive as the flea on the chariot axle, who, on looking back said proudly and complacently, "Lo, what a dust I have raised."

The Academy grew by leaps and bounds. In 1934 it numbered four hundred and seventy-five, in 1944 eight hundred and twenty-two, in 1954 one thousand, seven hundred and ninety-three, and in 1960 two thousand, six hundred and eighty-five. The acceptance of orthopaedics as a specialty both by the profession and by the public was most gratifying. The constant flow of letters from groups and communities wanting orthopaedic surgeons shows that the demand still exceeds the supply. Only continued vigilance in maintaining high standards of practice will keep our specialty respected and condoned.

As the Academy grew it gathered to it many activities that were never envisioned at the start. The popular Instructional Courses, at first a very controversial addition, have become one of the prime functions and the volume of Instructional Course Lectures is a valuable yearly addition to our literature. More recently we have seen the formation of satellite organizations scheduling meetings at the time of the Academy convention. We now have the American Society for Surgery of the Hand, the Research Society, various correspondence clubs, numerous alumni groups, Shriners' Hospitals Surgeons, Part II of the Boards, the Orthopaedic Research and Education Foundation, and other organizations, meeting. Our specialty is forming sub-specialties and we now have men primarily interested only in children's orthopaedic surgery, ar-

thritis, hand surgery, and basic research in orthopaedics. Such sub-specialties are legitimate children but total training and consideration of the entire individual will always be the foundation stone of good practice. We will have to be careful not to have too many satellite group meetings at the time of the Academy Convention or we will have people complaining of the total length of the meetings.

And so the vineyard has grown and those of us who have been privileged to have worked in many of the fields have developed deep affection for the endeavor. We have watched with anxious eyes while the storms have shaken the supports and with sorrow we have seen many of the wise, stalwart leaders go to rest. Association with selfless dedicated men guided and inspired only by the principles of service cannot avoid leaving a mark and a trail to follow. May our Academy always be fortunate enough to have men of the high caliber of its pioneers to guide its destinies.

Now for the future. It is evident that our formative period is over. The first twenty-five years has found us firmly established and with assets both spiritual and material. We have been concerned with building our own stature and we have neither assisted other orthopaedic organizations nor cooperated in joint efforts outside our country's boundaries. Our parent society, The American Orthopaedic Association, which many of us hold in the highest esteem, has for a number of years cooperated with The British and Canadian Orthopaedic Associations in conducting joint meetings. These have been highly successful and have tended to bind the societies together. Of even more importance has been the exchange of Fellows between these organizations. As you know, The Canadian and American Associations send young orthopaedic surgeons to Great Britain every other year and Great Britain responds in kind in the intervening years. A hard core of men who have had the experience of being Exchange Fellows has grown and their enthusiasm for the exchange has been hearty. Such knitting together of men and ideas in such manner has brought advancement and maturity to all involved organizations. Great Britain cooperates with other countries in other endeavors and it is interesting to note that wherever there is an orthopaedic meeting anywhere in this world of ours one or two prominent British orthopaedic surgeons are sure to be present and on the program. This is cooperative enterprise that pays dividends in knowledge and esteem.

Our Academy now is in position to make one of its most important decisions. Shall we remain an isolated group or shall we assume our rightful status and join hands with groups beyond our borders in an effort to improve the spread of knowledge and learn to know and respect our colleagues of other countries. It is impossible and unwise to spread out in all directions at once, but opportunely the chance of taking the first big step is close at hand. Last month, as already mentioned, I was privileged to be a guest at the Latin American Society of Orthopaedic Surgery and Traumatology in Santiago, Chile. This Society is, like ours, a rapidly growing organization, now about fifteen years old, with an attendance at the meetings of about six hundred. Examinations are now given as a measure of professional ability before admission. Practically all of the qualified orthopaedists of South and Central America and Mexico are members, and younger orthopaedists are growing in numbers rapidly in our sister continent. Already we have as Academy members twenty-seven orthopaedists of Latin America and conversely a few of us from the United States hold membership in the Latin American Society. A number of the men in our specialty in Latin America were trained as we were in the United States, but more were trained in Europe. A French text is almost standard. Europe has not neglected its ties with Latin America and it is interesting to note that leading orthopaedic surgeons from England, France, Germany, and Italy were prominently present in Santiago.

World War II brought us closer together with our South American colleagues than we had ever been, but the lack of joint enterprise following the war is permitting us to drift apart. It is now a time of decision. Will we join hands with the Latin American orthopaedic surgeons in cooperating in a joint meeting at some scheduled time and in establishing an exchange fellowship, or will we continue in our individual method? It seems to me that one way points to progress and the other to regression. The world is too small now. We need to know sooner what is going on in other countries, and they need to know more about us. This is not an aid program that is being proposed but an endeavor to bring two sister continents together for mutual improvement in our work. One could easily envision a Western Hemispheric Congress at some not too distant date, including Canada. Such a meeting initiated by the Academy would have a profound beneficial effect. The language barrier is of little consequence. Translators are always at hand and, moreover, many of our Latin American friends speak English. Paraphrasing Oscar Wilde, who said in speaking of England and the United States, "We are two countries divided by a single language," we might, orthopaedically speaking, be two continents united by different languages. The financing of Exchange Fellows could be done by donations and administered by the Academy or by the Orthopaedic Research Foundation, that very worthy organization, for the Academy. I can assure you that the project of exchange fellows and a joint meeting would be enthusiastically welcomed by the Latin American Society. I took the opportunity of sounding out a number of the members of the Society when I was in South America and I know that closer ties with their United States colleagues would be supported. It seems to be a proper time for the largest of all honorary orthopaedic organizations to extend a hand of welcome to a younger group who deserves encouragement and will appreciate our token of friendship. I propose that an Academy Committee be appointed to investigate the possibility of establishing an exchange fellowship program with Latin America and to report on the possibility of a joint meeting at some future date. This idea is not solely mine, as you may suspect. A number of Academy members have individually proposed the same project so it seems that the time is ripe for action.

In closing I must express my sincere appreciation to all the members of the Academy who have so loyally offered and given of their services in the past year. No President could have received more wholehearted support and I am deeply grateful. To all committee members who toil without recognition but with fruitful results I extend my thanks. To our Executive Secretary and to the most efficient secretaries, to whom by proximity to the Central Office I must have been a trial, my apologies for mistakes and my thanks. Lastly, my most sincere appreciation to the members of the Executive Committee and to the Secretary, Clinton Compere. Each person's method of conducting executive committee meetings is different and I realize that my method is sure to leave much to be desired. You have been patient, forgiving, and unsparing of your assistance. May you be blessed with more able leadership this coming year. As a postscript I humbly extend thanks to my long-suffering wife. Perhaps the number of absences from home and the number of wrinkles in the brow will now be reduced. It has been the most eventful year of my professional life, the most pleasant, and the most rewarding. To each of you my profound thanks.

Proceedings

AMERICAN ACADEMY FOR CEREBRAL PALSY

The Annual Meeting of the American Academy for Cerebral Palsy was held in Los Angeles, California, from November 30 to December 2, 1959, under the Presidency of Dr. Alvin J. Ingram.

Dr. Raymond R. Rembolt is President for the ensuing year.

The newly elected officers are:

President-Elect: George W. N. Eggers, M.D., Galveston, Texas;
Vice-President: Herman Josephy, M.D., Chicago, Illinois;
Secretary: Joseph D. Russ, M.D., New Orleans, Louisiana;
Treasurer: Samuel B. Thompson, M.D., Little Rock, Arkansas.

A Research Afternoon was devoted to the presentation of the fundamental neurophysiological research relevant to the field of cerebral palsy. Project descriptions and results were presented by outstanding workers in the field: W. Ross Adey, M.D., Carleton Hunt, M.D., Malcolm B. Carpenter, M.D., Miriam Lending, M.D.; Carmine D. Clemente, M.D.; James N. Yamazaki, M.D., and Liane B. Russell, M.D.

An innovation this year was the presentation of round-table discussions chaired by leading authorities as follows: "The Evaluation and Management of the Cerebral Palsied Child under Three Years of Age", Margaret H. Jones, M.D.; "Neurophysiological Aspects in Cerebral Palsy", John French, M.D.; "Physical Medicine in Cerebral Palsy", Jessie Wright, M.D.; "Bracing in Cerebral Palsy", Winthrop M. Phelps, M.D.; and "The Brain Damaged Child", Leslie B. Hohman, M.D.

The Instructional Courses given were: "The Diagnosis and Principles of Treatment of Cerebral Palsy", Meyer A. Perlstein, M.D.; "Orthopedic Surgery in Cerebral Palsy—Lower Extremity", George W. N. Eggers, M.D., *Chairman,* Harry E. Barnett, M.D., and Henry H. Banks, M.D.; "The Functional Treatment of Cerebral Palsy", George B. Deaver, M.D.; "Neuro-Physiological Basis of Cerebral Palsy", Chester A. Swinyard, M.D.; "Orthopedic Surgery in Cerebral Palsy—Upper Extremity", J. Leonard Goldner, M.D.; "Parent Counseling and Psychiatric Care in Cerebral Palsy", Henry Work, M.D.; and "Recent Advances in the Rehabilitation of Communicative Disorders", Martin F. Palmer, Sc.D.

A résumé of the Scientific Program follows:

Prognostic Classification in Cerebral Palsy. Dr. Kenneth B. Jacques[1] said that the classification of the various types of cerebral palsy (as well as most other medical conditions) is fairly well standardized. Such classification ordinarily is governed by the location and type of lesion, or clinical manifestations, or a combination of these. Another type of classification appears to be in order, if practical and realistic goals are to be achieved with the maximum efficiency and the minimum expense of man hours and resources.

The ultimate goals may be classified roughly into three categories, depending on the accomplishments, independence, or dependence of the patient. In the first group would fall those who can be expected to get an education, in the second group all those who can take care of their own personal needs. The third group would fall in a more dependent category, requiring care twenty-four hours a day whether at home or in an institution.

If the goal for a patient is changed, then the entire program of treatment may be changed and the maximum efficiency be attained, thereby doing the most good for the most patients, spreading the limited resources where they would be most effective.

Respiratory Patterns in Athetosis. William B. Plotkin, Ph.D.[2], and Dr. Meyer A. Perlstein analyzed the basic patterns of breathing in seven severely athetoid children as part of a larger study on the use of the electrolung in the normalization of such patterns. As might be expected, it was found that the respiratory rate was more irregular and more rapid in the athetoid child than in the normal, and that the vital capacity and other ventilation constants were also deficient.

On investigation of the ventilation equivalent of these children, a rather interesting observation was made. The athetoid children have an inefficient respiratory physiology which makes it necessary for them to breathe a larger volume of air than the normal child to obtain the same degree of oxygenization. This results in hyperventilation and loss of alveolar carbon dioxide. The implications of these findings are that some of the hyperirritability of the athetoid child may be intensified by a state of chronic respiratory alkalosis.

1. 3875 Wilshire Boulevard, Los Angeles 5, California.
2. 111 North Wabash Avenue, Chicago 2, Illinois.

A Study of Breathing Patterns of Cerebral Palsied Children. MR. JAMES C. HARDY[3] and DR. RAYMOND R. REMBOLT reported that in the literature dealing with speech problems of individuals who have cerebral palsy, mention is made of the high incidence of their associated breathing anomalies. Since many speech problems found in this group may be related to a problem of breath control, aiding the children to improve their control of respiration and thereby to improve their speech has become generally recognized as desirable. Thus, speech therapists need to be able to (1) make accurate diagnoses of breathing irregularities of the cerebral palsied; (2) ascertain whether such irregularities as may be found are related to a speech problem; and (3) determine the effectiveness of therapy designed to eliminate or alter the irregularities. The need for objective and quantified data which describe these breathing irregularities seems obvious. Furthermore, the variables operating to produce or modify such irregularities need to be identified.

A long-range program of respiratory research has been undertaken at the University Hospital School, State University of Iowa. The respiratory patterns of two experimental groups, spastic and athetoid, are being studied. A Collins respirometer and an oral manometer are being used to study air flow during certain speech activities, lung volumes, and the mechanics of breathing. Kymographic tracings of abdominal and thoracic expansion-contraction are being made concomitantly with the spirogram by the use of pneumographs.

Normal children and those with muscular dystrophy are being used as control groups. The latter group is being used to give an indication of how the respiratory measures vary in a group of children having problems of muscular weakness rather than problems of control of the respiratory musculature, as in children with cerebral palsy.

Over fifty specific measures are being collected from each experimental procedure, with each subject participating in a number of procedures. A recorded speech sample and a thorough analysis of oral involvement are made for each child.

The data are incomplete at the present time, but they already suggest results which may have immediate clinical application as well as implications for further research.

Cerebellar Ataxia with Sex-Linked Inheritance. DR. PETER COHEN[4] and DR. NATHAN MALAMUD described two patients with progressive degenerative disease of the central nervous system with a changing neurological picture. The outstanding clinical features showed a gradual change from an initial cerebellar to an extrapyramidal syndrome. The authors also presented a pedigree showing that this condition was present in other members of the family, occurring only in the males and transmitted through the females.

A Study of Growth Patterns in Cerebral Palsy. DR. JEROME S. TOBIS[5], DR. PHOEBE SATUREN, DR. GEORGIA K. LARIOS, and DR. ABRAHAM O. POSNIAK said that they found the height and weight of seventy severely handicapped cerebral palsied children to be significantly below the standards for American school children, as found in Simmons' data.

An investigation of the relationship of the patients' clinical status to their deviation from accepted norms in size was discussed.

The authors further said that an attempt was made to correlate growth patterns in cerebral palsy with motor involvement, functional activity, intelligence, nutrition, and other factors.

Muscular Weakness in Children. DR. FRANK M. HOWARD, JR.[6], DR. ROBERT G. SIEKERT, and DR. HADDOW M. KEITH reported that it is common for children with muscular weakness to seek attention at clinics for either crippled children or for those with cerebral palsy, even if the gait disturbance or other disability manifests itself after normal development. They said that at times the diagnosis may present difficulties, and discussed several diseases in which muscular weakness is a prominent feature. These include: myositis (polymyositis and dermatomyositis), muscular dystrophy, neuronitis (polyneuritis), and myasthenia gravis. Stress was laid on careful clinical evaluation. Reference was made to the aid derived from muscle biopsy, electromyography, and serum enzyme determination (glutamic-oxalacetic transaminase). Accurate diagnosis is essential since treatment and prognosis will vary greatly from that of cerebral palsy.

The Electromyogram and Motor Behavior as Diagnostic Aids in Differentiating Hypotonic Cerebral Palsy. Amyotonia Congenita and Benign Congenital Hypotonia. DR. ERNEST W. JOHNSON[7], DR. ROBERT JEBSEN, DR. HILDA KNOBLOCH, DR. MAY SCHMIDT, and DR. DONALD K. GRANT defined hypotonia as a reduction in motor activity manifested especially by decreased spontaneous movement, poor postural adjustment, and decreased resistance to passive

3. University Hospital School, State University of Iowa, Iowa City, Iowa.
4. University of California Hospitals, San Francisco 22, California.
5. 1 East 105th Street, New York 29, N. Y.
6. Mayo Foundation, Rochester, Minnesota.
7. Ohio State University Hospital, Columbus 10, Ohio.

movement. This lowered level of motor activity may be due to abnormalities of the motor unit, of the central nervous system, of the afferent pathways, and, perhaps, of the muscle spindle system. Metabolic abnormalities may secondarily affect these areas, producing hypotonia.

Thirty-one cases of infantile hypotonia were studied with the electromyograph and the developmental and neurological examination of Gesell. Of these, eighteen were diagnosed as brain damage, four as Werdnig-Hoffmann disease, one as polyneuritis, four as anterior-horn-cell disease of unknown type, one as metabolic myopathy, and three, tentatively, as benign congenital hypotonia.

The results of the electromyographic and developmental examinations for each diagnostic category were presented and discussed. It was felt that the developmental and neurological examination of Gesell is helpful in detecting damage to the central nervous system as a cause of hypotonia, and that the electromyograph is useful in differentiating the motor-unit disease as the underlying cause.

In the authors' experience, the majority of infants exhibiting hypotonia have brain damage. Such infants occasionally may demonstrate neuropathic electromyograms, perhaps on the basis of a single insult to both the brain and the spinal cord. Although some brain-damaged hypotonic infants later become athetoid, spastic, epileptic, or mentally deficient, many completely or partially compensate for their early neuromuscular disability.

The Development of Refractive Characteristics in Cerebral Palsy. Dr. Eric W. Fantl[8] and Dr. M. A. Perlstein said that children with cerebral palsy have a greater number of eye abnormalities than normal children. In the severely handicapped cerebral palsied, one is struck by the high percentage of patients who wear glasses.

Most reports on eye abnormalities in cerebral palsy have dealt with eye-muscle involvement, visual acuity and perception, and developmental anomalies. Little attention has been paid to the nature of the refractive error.

Children normally are hyperopic in infancy and early childhood and gradually tend to become more myopic with advancing age, emmetropia being reached somewhere between the ninth and twelfth year. In children with athetosis, however, the normal tendency for the refractive characteristics of the lens to change from hyperopia to myopia was found not to exist. In these children, the original hyperopia tended to persist long after it would normally be expected to become emmetropic or myopic. As a result, hyperopia with or without astigmatism is a more common refractive error in the athetoid than in the spastic or other types of cerebral palsied children, whose refractive development tends to follow the normal path. In spastic children, particularly those associated with a history of prematurity, myopic errors of refraction were more common.

Recognition and Management of Ocular Handicaps in the School Age Cerebral Palsied Child. Dr. Stanley Diamond[9] emphasized that the recognition and management of ocular defects are important for the education and rehabilitation of the cerebral palsied child of school age. Ocular handicaps occur in a high percentage of these children and may constitute major hurdles in their training.

A review of school-age children with cerebral palsy examined by the author showed the most frequent reason for referral was for an estimation of the degree of vision present. Subnormal vision constituted the greatest educational and training handicap. Ocular-motility problems formed the next largest group. Other, less frequent causes for referral were the following defects: refraction problems, ocular headaches, reading problems, and visual aphasias.

The Prognosis for Speech Deficiencies in Cerebral Palsy. Dr. Edward J. Lorenze[10], Dr. Martin Sokoloff, and Dr. Roberto Cruz determined that of 192 cerebral palsied patients seen, 84.4 per cent had speech problems. After minimum follow-up of three years, the patients were re-evaluated to determine the initial diagnostic accuracy and the rate of progression during the follow-up period. The causes of delayed speech development were felt to be mental retardation in 44.3 per cent, aphasic-like disturbance in 4.2 per cent, perceptual disturbances in 6.2 per cent, severe articulatory disturbance in 5.7 per cent, emotional disturbance in 4.2 per cent, social retardation in 5.2 per cent, and hearing impairment in 3.6 per cent. The causes of disorders in speech production were felt to be dysarthria in 13.5 per cent, ataxic dysarthria in 3.1 per cent, dyslalia in 7.8 per cent, dysphonia in 0.5 per cent, disturbances of resonance in 1.6 per cent, dysrhythmia in 1.6 per cent, and stuttering in 1.6 per cent.

Observations on the Diplegia of Prematurity. Dr. William R. Duncan[11] and Dr. Garth Mooney presented a study of forty diplegic patients with a background of prematurity.

8. 111 North Wabash Avenue, Chicago 2, Illinois.
9. 350 Post Street, San Francisco 8, California.
10. 785 Mamaroneck Avenue, White Plains, New York.
11. 1607 Medical-Dental Building, Seattle 1, Washington.

A Genetic, Metabolic and Clinical Study on One Hundred Cerebral Palsied Children. DR. JOHANNA BLUMEL[12], DR. E. BURKE EVANS, and DR. G. W. N. EGGERS reported the results of this investigation, including complete genotyping and electrophoretic hemoglobin and serum studies on 100 (fifty-eight male and forty-two female) children with cerebral palsy.

The work is now in progress at the Moody State School for Cerebral Palsied Children and John Sealy Hospital, University of Texas Medical Branch, Galveston, Texas.

The Role of the Medial Hamstrings and Gracilis in Development of Hip Pathology. DR. RICHARD A. DODELIN[13] and DR. LENOX BAKER studied the problem of neurological dislocation in cerebral palsy with reference to the role of certain thigh muscles. The roentgenographic findings in children with adduction deformity of the hip were summarized. The possible etiology and the prevention of neurological dislocation were also discussed.

A Collaborative Project for the Study of Cerebral Palsy, Mental Retardation and Other Neurological and Sensory Disorders of Childhood. DR. CRAIG MACKLE[14] and DR. HEINZ BERENDES discussed the impact of this project on the maternity hospital and the university hospital. Studies related to the collaborative project were further discussed by Dr. David B. Clark.

12. University of Texas Medical Branch, Galveston, Texas.
13. Medical Arts Building, Columbus, Georgia.
14. 330 South 9th Street, Philadelphia 7, Pennsylvania.

THE PIEDMONT ORTHOPAEDIC SOCIETY

The Piedmont Orthopaedic Society, a group of orthopaedic surgeons practicing in various parts of the country who have in common the location of their training, particularly at Duke University, met at Ponte Vedra, Florida, on May 21, 22, and 23, 1959. The *Chairman* of the meeting was Dr. James F. Funk, Atlanta, Georgia.

Members of the Executive Committee are: Dr. Walter A. Hoyt, Jr., Akron, Ohio; Dr. Jack Houston, Columbus, Ohio; Dr. Ned M. Shutkin, New Haven, Connecticut; and Dr. J. Leonard Goldner, *Secretary-Treasurer.*

A résumé of the papers presented follows:

Case Report of Metaphyseal Dysostosis. DR. F. WAYNE LEE[1] said that metaphyseal dysostosis is an exceedingly rare condition which has not been previously reported in this country. The characteristic feature of the disease is that the metaphyses of all the long bones consist almost entirely of unossified cartilage. The roentgenographic appearance is unique and differs considerably from that seen in dyschondroplasia.

The case reported by Dr. Lee was of a girl first seen at a crippled children's clinic near Charlotte in October 1956, when she was four years old. The child showed gross shortening with obvious deformities throughout both the upper and the lower extremities. The skull was macrocephalic and the chest was elongated and barrel-shaped. She walked with difficulty and she had a waddling gait. Roentgenograms showed the typical, poorly developed, and grossly distorted metaphyses with normal epiphyses in their proper alignment.

No recommendations were made regarding treatment—the case was presented purely for scientific value.

Ostamer. DR. PAUL C. THOMPSON[2] said that he had used ostamer in four patients with various orthopaedic conditions. Technically, the operation was unsuccessful on two attempts because of improper hemostasis, although a satisfactory result may later be obtained. The other two patients (one with fracture of the femoral neck) had satisfactory results, with excellent immobilization of the lower part of the tibia.

There are many technical difficulties that must be considered when attempting to utilize ostamer for fracture immobilization. The importance of hemostasis, and proper temperature, mixing, and compression of the material into the fracture site should be further emphasized.

Report on Traumatic Dislocations of the Hip in Children. DR. JAMES FUNK[3] said that the case reports of ten children with traumatic dislocation of the hip were presented at the Annual Meeting of the Piedmont Orthopaedic Society in 1958, and at that time it

1. 225 Hawthorne Lane, Charlotte 4, North Carolina.
2. 307 McCallie Avenue, Chattanooga 2, Tennessee.
3. 1938 Peachtree Road, N.W., Atlanta 9, Georgia.

was decided to make investigation of this condition a project for the Society. The enlarged series of thirty-four patients presented at the 1959 meeting included additional cases largely contributed by the Society. As in the original series, the patients seem to fall naturally into three age groups, with fairly typical findings in each. In general, the youngest group—two to four years of age—suffered easily reducible dislocations from relatively minor trauma; the end results were excellent. The middle group—six to ten years of age—as a rule sustained more severe trauma; several of these children had residual hip disability and several required open reduction. In the older group—eleven to fourteen years of age—dislocation usually resulted from violent trauma. In the cases where early reduction was effected the results were generally good.

Because the treatment varied considerably it was difficult to correlate the end results with the therapy employed. In general, the treatment consisted in a period of postreduction traction and delayed weight-bearing. It is hoped that with the passage of time, a more significant analysis of the results can be made, and additional conclusions drawn. It is planned to analyze this group of patients again in 1960.

Congenital Scoliosis. Dr. Garry DeN. Hough, III [4], reviewed the findings in eighty-seven patients with congenital scoliosis seen at the Shriner's Hospital for Crippled Children, Springfield, Massachusetts. Fifty patients showed vertebral anomalies, and twenty-four patients without anomalies had known scoliosis before the age of three. Roentgenograms of the remaining thirteen patients were not available.

Sex distribution was equal. A right dorsal-left lumbar pattern predominated. Growth charts of thirty-nine patients followed more than five years usually showed relentlessly increasing curvature with or without therapy. The rate and extent of progression were so variable that individual prognosis proved hazardous. The efficacy of various therapeutic regimens could not be judged.

Single vertebral anomalies were poorly represented. Thirty-seven patients showed multiple fused vertebral segments with associated anomalies of the posterior elements and (usually) ribs. By adolescence lateral curvatures in excess of 90 degrees developed in one-half of these patients. Of twenty-four patients without bone anomalies, nineteen progressed to adolescent curvatures of 80 to 125 degrees, often despite spine fusion. Five patients showed unexpected regression. By age five, these curvatures were less than 40 degrees, whereas all other patients had curvatures over 50 degrees at this age. One intermediate case was noted. Follow-up to adulthood of two patients showed some further progression.

Recurrent Tibial Deformities after Osteotomy. Dr. Richard A. Dodelin [5] reported on the tibial osteotomies performed at Georgia Warm Springs Foundation on patients with poliomyelitis to correct one or more of the components of the triad of knee deformities which results from poliomyelitis—external tibial torsion, valgus deformity, or recurvatum. All patients were followed for five years. There was a total of 491 operations performed on 297 patients. There were 109 recurrences. The results according to the age of the patient at the time surgery was performed are as follows: Four to six years (twenty-six operations), 81 per cent recurrence; seven to eight years (forty-one operations), 69 per cent recurrence; nine to ten years (eighty operations), 45 per cent recurrence; eleven to twelve years (eighty-seven operations), 21 per cent recurrence; thirteen to fourteen years (fifty-five operations), 6 per cent recurrence; fifteen to sixteen years (thirty-eight operations), 2 per cent recurrence; and seventeen years and over (164 operations), 1 per cent recurrence.

When there is need to improve alignment to fit braces, or to remove a disfiguring deformity, or to prevent compensatory changes, particularly in the foot, tibial osteotomy should be carried out. The likelihood of a repeat osteotomy at a later date should not alter this program.

Bicipital Tendon Disorders. Dr. John B. Feltner [6] discussed forty-two patients in whom the bicipital tendon was the primary cause of shoulder symptoms. Thirty were treated non-operatively, and twelve were operated on after failure of non-operative treatment. The differential diagnosis in these patients was, mainly, disorders and injuries of the rotator cuff, or bursitis, or cervical neuritis.

Common symptoms and findings in bicipital tendon disorders were: pain in the shoulder; radiation of pain down the arms, even into fingers; localized tenderness in the bicipital groove; and aching pain in the biceps muscle. In many instances, there was but little restriction in range of motion. Internal rotation, such as reaching into the hip pocket, often causes distress. Abduction was often not restricted, in contrast to disorders of the supraspinatus tendon. Roentgenograms were negative.

The most effective non-operative treatment is to put the arm at rest. Exercises aggravate bicipital tendonitis. Relief of symptoms and improvement after local injection into the bicipital groove confirm the diagnosis.

4. 146 Chestnut Street, Springfield 3, Massachusetts.
5. Medical Arts Building, Columbus, Georgia.
6. 700 Main Street, W., Rochester 11, New York.

Operation was carried out on twelve patients after they failed to improve with ample time and conservative therapy.

The principal finding at operation was an adherent and non-gliding section of biceps tendon in the bicipital groove. In two patients with old ruptures of the biceps tendon distal to the groove, persistent shoulder symptoms were found to be caused by the adherent intra-articular portion of the tendon. Symptoms were relieved by excision of this portion of the tendon. Resection of the intra-articular portion of the bicipital tendon and fixation of the distal portion of the tendon into freshened bone surface of the bicipital groove resulted in the return of good function and full motion. The patients so treated—a painter, a baseball player, and an electrician, among others—were able to resume their former occupations. Two patients, unrelieved by previous shoulder operations without exploration of the tendon in the bicipital groove, were finally relieved by the operation just mentioned, which suggests, in most cases, the desirability of exploring this area.

Manipulation for Low-Back Pain. Dr. Howard J. Schaubel[7] said that he saw daily a number of patients with disabling low-back pain, the cause of which could not be detected, despite thorough examination and roentgenographic evaluation.

The principles of conservative treatment of low-back pain should include more than rest, heat, traction, massage, medication, or braces. The orthopaedic surgeon should recognize the therapeutic value, as well as the limitations, of spine manipulation, and adapt it as an integral part of his armamentarium when it is indicated.

Chronic low-back pain of indefinite etiology is most probably caused by a periarticular fibrositis or adhesive capsulitis involving the joints of the spine and their surrounding tissues. The problem is similar to that of the frozen shoulder and manipulation should be considered.

Acute injuries to the low back probably cause tears of the muscles, connective tissues, and joint capsules, along with some degree of impaction or distraction and subluxation of the articular facets. Muscle spasm is invariably associated with this syndrome.

The technique of manipulation was based on the normal range of motion of the joint being manipulated. The manipulation must be carefully designed and executed; it is in no sense a motion of brute force. Because of the limited indications for manipulation in the treatment of backache, the differential diagnosis of low-back conditions becomes of utmost importance. Careful diagnostic investigation must be made before manipulation is considered. Contra-indications for manipulation are pathological conditions elsewhere than in the back, tuberculous spondylitis, neoplasm, and the like.

Repair of Rotator-Cuff Injuries in Elderly Patients. Dr. William T. Davison[8] reported that in a series of sixty patients, whose initial diagnosis suggested an injury to the rotator cuff of the shoulder, ten proved to have massive transverse tears of the rotator cuff. Useful findings in establishing the diagnosis were: (1) The rapid onset of atrophy of the supraspinatus and infraspinatus muscles in the absence of the atrophy of the deltoid, so characteristic of other shoulder disabilities; (2) the maintenance of a full range of painless motion; and (3) weakness, pain, and occasional complete loss of power when the patient attempts to abduct with the torn portion of the rotator cuff placed directly over the superior portion of the head of the humerus.

Of great importance in the operative correction was the adequate lengthening of the rotator cuff by division of the synovial adhesions between the superior rim of the glenoid and the rotator cuff, permitting the tendon to be reinserted into a trough within one centimeter of its normal insertion. Nine patients on whom this was done had excellent results and were able to return to their regular work, which required a strong, painless, and fully mobile shoulder.

7. 124 Fulton Street, E., Grand Rapids 2, Michigan.
8. 1108 Military Street, Port Huron, Michigan.

THE RUSSELL A. HIBBS SOCIETY

The Annual Meeting of the Russell A. Hibbs Society was held in Oklahoma City, Oklahoma, on May 29 and 30, 1959, at the University Hospitals with Dr. William L. Waldrop, *President,* presiding.

Dr. Floyd E. Bliven, Jr., Augusta, Georgia, was unanimously elected to membership. Dr. Richard H. Kiene, Kansas City, Missouri, was unanimously elected *President* for the year 1960, and Dr. Nicholas J. Giannestras was unanimously re-elected *Secretary-Treasurer.*

Summaries of the papers presented follow:

DR. DON H. O'DONOGHUE[1] presented a series of patients and demonstrated treatment and end results:

1. The use of the Mustard procedure to correct a severe abductor lurch in a post-poliomyelitic patient. The result was satisfactory.

2. Tuberculosis of the hip which had been treated by an arthrodesis of this articulation with successful outcome.

3. Treatment of bilateral fractured femora with skeletal traction in the so-called 90-90-90 position (with the hips and knees at 90 degrees and the ankles at right angles), using Kirschner wires through the lower femoral condyles.

4. Radio-ulnar synostosis and possible treatment.

5. The use of cuneiform osteotomy to correct a slipped upper femoral epiphysis with an excellent end result.

6. Transplantation of the tibialis anterior muscle group after an attack of acute anterior poliomyelitis. The postoperative result was excellent.

7. Fracture of the distal tibial epiphysis with closed manipulation with excellent realignment and healing. Discussion of fracture through the epiphyses then ensued.

8. Diastasis of the distal tibiofibular joint due to an avulsion fracture of the fibula, but with no tear of the distal tibiofibular ligaments. A discussion of recognition and treatment was carried out.

Orthopedic Memories of Russell Hibbs. DR. W. KELLY WEST[2] gave an extremely interesting presentation about an outstanding man in orthopaedic surgery.

Reconstruction of Anterior Cruciate Ligaments. DR. DON H. O'DONOGHUE[1] presented a new procedure for repair of the anterior cruciate ligaments. The procedure consisted in a lateral approach with the development of the iliotibial band, as well as a portion of the fascia, into a strip of viable tissue, fourteen inches long and two inches wide, which was dissected free down to the level of the lateral femoral condyle. It was anchored there by a staple. This strip was then threaded through a hole drilled through the lateral aspect of the tibia to the anterior edge of the articular cartilage of the tibia in the mid-line, then through the lateral femoral condyle, and subsequently sutured on itself.

Dr. O'Donoghue presented fourteen to fifteen patients on whom this procedure had been performed; several expressed marked relief of their symptoms after this operation. Dr. O'Donoghue said that up to the present time he is quite pleased with the end results.

Bone Stress Research. DR. WILLIAM HARSHA[3] reported the results of studies of the effect of known distracting forces across the distal femoral epiphyses of growing mongrel dogs and goats. Stainless-steel springs were affixed to the femora proximal and distal to the epiphyseal plate and were adjusted to deliver a known distracting force through a set range of excursion. A force of three times the weight of the animal routinely avulsed the epiphysis. Epiphyseodesis occurred in many of the animals with distracting forces of less than body weight. This usually happened after sufficient growth in the length of the bones had occurred to use up all the excursion of the springs despite the fact that the device was so constructed that no resistance to the growth force could occur. Since the amount of distracting force produced by the springs proved to be unpredictable, the springs on each side of the bone were replaced by cylinders filled with freon gas at sufficient pressure to deliver the desired distracting force. These devices were so constructed that the gas pressure could be maintained by periodic percutaneous injections of gas, thus eliminating the need for repeated operations. To date, the gas cylinders were used in four animals, in two of which there occurred statistically significant increases in femoral length as compared with the opposite side.

A series of experiments to test the effects of different pressures is now under way and histochemical studies at various stages of epiphyseal growth are being planned.

Further Observations on V-Type Patellectomies. DR. HOWARD B. SHORBE[4] discussed further the patellectomy described in *The Journal of Bone and Joint Surgery*, **40-A**: 1281-1284, Dec. 1958.

Several patients were presented for examination and evaluation; the results appeared quite satisfactory. One patient whose knee was re-explored demonstrated that the patellar tendon, the femoral condyle, and the synovial membrane appeared perfectly normal after patellectomy one year previously. There was no chondromalacia of the femoral condylar notch.

Hip Joint Acetabular Prosthesis. DR. EARL MCBRIDE[5] said that the acetabular prosthesis consisted of a Vitallium cup with a rimmed edge with three fins on the posterior surface

1. 1111 North Lee Street, Oklahoma City 3, Oklahoma.
2. 1200 North Walker Street, Oklahoma City 3, Oklahoma.
3. University Hospitals, Oklahoma City 4, Oklahoma.
4. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
5. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.

of the cup which would embed themselves into the underlying bone, thus immobilizing the prosthesis. Dr. McBride presented several patients who had had this prosthesis and had had very satisfactory results. Dr. McBride said that he has been using this type of prosthesis for the past five years.

The best surgical approach is the U-flap exposure with osteotomy of the greater trochanter with the muscular attachments. This permits a better exposure of the hip joint. His experience over the five years led him to make the following observations: (1) that the capsule should not be removed when performing this procedure; and (2) with this acetabular prosthesis the weight-bearing force of the femur comes up into the acetabular prosthesis. This procedure was performed for Otto pelvis in three patients; osteo-arthritis of the hip in nine patients; avascular necrosis of the head of the femur in four patients; fracture-dislocation of the hip in one patient; rheumatoid arthritis in two patients; Smith-Petersen cup revision in one patient; and villonodular synovitis of the hip in one patient.

Joint Injections with Nitrogen Mustard and Dornovac. Dr. J. N. Owens [6] discussed the treatment of rheumatoid arthritis and villonodular synovitis of the knees and other readily accessible joints by the injection of 100,000 units of dornovac, a pancreatic mucolytic enzyme, which reduces boggy synovial thickening of the synovial membrane in rheumatoid arthritis, followed by the injection of a mixture of 0.2 milligram of nitrogen mustard, twenty milligrams of hydeltrasol, and fifty milligrams of hydrocortone TBA, freshly prepared. The average patient received three to five daily injections initially and one repeat injection every six months. Dr. Owens warned that this material must be freshly prepared and must be discarded if it has stood for more than fifteen minutes after preparation. Rubber gloves should be used to avoid burns and only those joints in which the position of the needle can be established with certainty should be injected. For this reason the hip should not be treated by this method.

Two patients were presented with villonodular synovitis of the knee. Both had had recurrence of their symptoms after surgery and both had experienced marked relief of their symptoms after injection. Dr. Owens reported that with the use of radioactive tracers it had been shown that the hydrocortone was deposited in the mesenchymal cells of the synovial membrane.

Discussion of Hand Surgery with Illustrated Cases. Dr. Daniel Riordan [7], Dr. E. Crampton Harris, Jr. [8], and Dr. William L. Waldrop [9] discussed many unusual problems in hand surgery and hand reconstruction which had been treated by Dr. Waldrop of the McBride Clinic.

Arthrodesis of the Shoulder. Dr. Charles Rockwood [10] described a technique for arthrodesis of the shoulder in which rigid fixation of the arthrodesed joint after denudation of the joint surfaces was achieved with a metallic screw. Firm fixation, maintaining contact between opposing cancellous bone surfaces, was accomplished, and fusion was successful in all cases. The amount of abduction of the humerus, with reference to the scapula, was determined by roentgenogram at the time of operation. It was recommended that this procedure not be done in children under ten years of age since loss of motion had occurred when fusion was done on those children who were younger than ten years.

The Metabolism of Fracture Healing. Dr. Richard W. Payne [11] discussed the remarkably rapid and dynamic systemic responses of the body after fracture. These responses include shock, a fall in serum albumin, and loss of nitrogen, calcium, phosphorus, and potassium in the urine. All these processes appear to be important in setting the stage for proper fracture healing.

Success in fracture healing is largely determined within the first one to two weeks. During this period the fracture ends are denuded back to the anastomoses of the Haversian canals. Chondroblasts derived from cells of the periosteum and endosteum make their appearance and form permeable young bridging cartilage which is capable of transmitting nourishment by diffusion.

The importance of an inductor factor, which has been identified as an acid mucopolysaccharide, was discussed. The majority of available evidence indicates that the early cartilage is composed of mucopolysaccharides which are replaced by neutral mucopolysaccharides during the aging process. In developed organic matrix the intervening ground substance is largely neutral mucopolysaccharide. The splitting of the sugar moieties from these glycoproteins (probably by osteocytes) to form the protein collagen immediately precedes ossification.

6. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
7. 1538 Louisiana Avenue, New Orleans 15, Louisiana.
8. 157 Louisville Street, Mobile, Alabama.
9. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
10. University Hospitals, Oklahoma City 4, Oklahoma.
11. 801 N.E. 13th Street, Oklahoma City 4, Oklahoma.

Several agents of importance to fracture healing included vitamins A and C, glucocorticoids, pituitary growth hormone, aminonites, estrogens, androgens, protein and amino acids, parathyroid hormone, and alkaline phosphatase.

Unusual Amputation and Unusual Prosthesis-Function Bracing of the Upper Extremity. Dr. William L. Waldrop[9] reported on six patients who presented unusual problems in the fitting of prostheses to give some function of either the upper or the lower extremity. Dr. Waldrop said that he is extremely fortunate in having a prosthesis manufacturer, a double amputee, who understands the problems involved in the proper fitting of prostheses. The main conclusion of Dr. Waldrop's presentation was that each amputee was an individual problem and could not be handled in a routine matter. If the physician devotes the time necessary to devise and to fit a prosthesis adequately, it not only can be quite serviceable, but will be used by the patient with facility and satisfaction.

Diseases of Mesenchymal Tissue. Dr. William K. Ishmael[10] discussed each type of collagen and mesenchymal disorder. He stressed that the handling of a patient with this kind of disease requires an entire team and involves many specialties.

When antibiotics are used in the treatment of rheumatic fever, streptococcal infections are controlled, and, consequently, there are no recurrences of the initial attack. Rheumatic fever is an unusual type of infection since it produces no bone and joint changes despite the inflammatory reaction; the changes occur only in the heart.

Rheumatoid arthritis is characterized by joint symptoms but it is capable of mimicking various diseases. In the treatment of this disease Dr. Ishmael has used chloroquine phosphate with good results. While on this medication patients have shown very little progression of the disease, whereas when the medication was discontinued there was definite regression. Dr. Ishmael presented a patient whose rheumatoid arthritis had been controlled with the continual use of chloroquine phosphate for five to six years.

In rheumatoid spondylitis 75 per cent of the patients have remissions. The pain is adequately controlled with phenylbutazone. Subsequent surgical correction of the kyphosis by arthrotomy of the spine has been performed with excellent results. The patient presented was given phenylbutazone (butazolidin) intermittently.

The diagnosis of systemic lupus erythematosus is quite difficult and the ideal manner in which to substantiate this diagnosis is by biopsy. Systemic tests are not always helpful. These patients are extremely photosensitive and it was found that oxsoralen protects the patient against the sun. The method of treatment recommended for this disease is the use of nitrogen mustard and ACTH gel.

In diffuse scleroderma there is cardiac, kidney, and arteriosclerotic involvement. The diagnosis is made by skin biopsy as well as clinical appearance. Narcosynthesis has been used with some success since it controls the basal motor phenomena. Nitrogen mustard with the narcosynthesis has been used as therapy in this condition but the results have been rather discouraging.

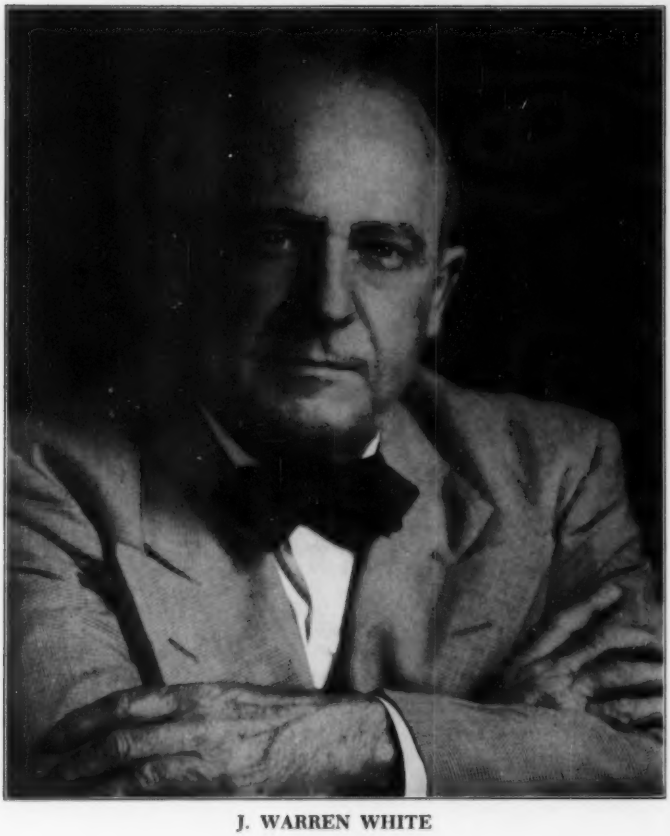
In local scleroderma there are no systemic manifestations. The patients also demonstrate extreme photosensitivity along with Raynaud-like phenomena. Dramatic relief is observed with the use of narcosynthesis and oxsoralen.

The diagnosis of periarteritis nodosa must be made on the basis of the clinical appearance reinforced by biopsy. The treatment consists of intravenous corticotropin supplemented with nitrogen mustard. Usually four to five daily injections are necessary in order to control this disease. This entity may cause death rapidly and, prior to the use of intravenous corticotropin with nitrogen mustard it usually was a rapidly fatal disease, since the process would become an irreversible one. With this therapy, however, the changes can now be reversed and fatality is rather rare. It was also brought out that in some instances, extreme photosensitivity has been observed with this disease.

Dermatomyositis is localized to the skin and muscles only. It is characterized by Raynaud-like phenomena. The hands are usually somewhat congested and bluish in color. However, there are no changes in vital organs. This condition responds quite satisfactorily to nitrogen mustard therapy as well as the use of plaquenil to protect against sensitivity to the sun.

Hypercortisonism is an iatrogenic disease. It may mimic any and all of the various mesenchymal-tissue diseases but primarily it is a necrotizing disorder. The treatment in this condition consists of intravenous hydrocortisone drip, multiple transfusions, narcosynthesis to control the Raynaud-like phenomena, and plaquenil to control sensitivity to the sun.

12. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.



J. WARREN WHITE

1892 – 1959

"For some we loved, the loveliest and the best
That from his Vintage rolling Time hath prest.
Have drunk their Cup a Round or two before
And one by one crept silently to Rest."

Warren White was, most of his professional life, a transplanted New Englander. Lifelong asthma precluded rigorous northern winters. He was born in Boston, attended Roxbury Latin School, graduating in 1909, and last June was present at the fiftieth anniversary of that class. He graduated from Harvard College in 1913 and from Harvard Medical School in 1917. He served as a regular officer in the Medical Corps of the Navy until 1923. From 1921 to 1923 he was in charge of the Orthopaedic Service at the Chelsea Naval Hospital.

After a year of private practice in Boston, Dr. White in 1924 went to Hawaii as first Chief Surgeon at the Shriners' Hospital for Crippled Children in Honolulu. In 1927 he moved to Greenville, South Carolina, to become Chief Surgeon at the Shriners' Hospital in that city. He remained there for twenty-two years, returning in 1949 to Honolulu to again resume the post he had left in 1927. In 1953 he joined the Straub Clinic in Honolulu. In 1957, at the mandatory age of sixty-five, he retired from the Shriners' Hospital, having completed thirty-three years of service at Greenville and Honolulu. During all these years, in addition to his work for crippled children, Dr. White had an extremely active practice in orthopaedic surgery which he continued until his death.

Everywhere Warren White went he made warm friends and ardent admirers among his colleagues and patients. His manner of speech and even his gait gave evidence of the boundless energy and drive that carried him on to an amazing volume of work. To balance his potential for hard work he had a sense of humor which enabled him to laugh with others and at himself, if need be. He had great mechanical skill and perception which led him to devise many instruments and techniques which are used by orthopaedic surgeons.

Repose was not in his nature. While driving his car long distances to and from crippled-children's clinics in South Carolina, he frequently dictated his clinical observations and operative notes to his ever-present dictaphone. As far as this writer knows no untoward event happened to mar this breach of safe driving.

Dr. White had prior warnings of what might eventually happen to him. After his first coronary attack he told me that his brother, Dr. Paul Dudley White, had told him to carry on as usual. In all probability the cardiologist knew that the orthopaedic surgeon in question could and would in no way do otherwise.

His final attack occurred on September 12, 1959, a Saturday afternoon, when he was floating on a rubber life raft at Waikiki Beach with his ever-present camera. He was taking pictures of the new apartment house that the Whites had just moved into, intended for a Christmas card. He had completed the roll of film. It is a comfort to know that at the end he was engaged in his beloved hobby of photography at which he excelled.

Not the least among Warren White's gifts and talents was that of friendship. It is the lot of few to be loved and admired as he was. In a sense he was a joiner. He belonged to the Aesculapian Club, the Rotary, the Elks, and the Adventurers and was a Scottish Rite Mason, a Shriner, and a Jester. He served as a trustee of Furman University from 1938 to 1949.

Among the professional organizations to which he belonged are the American Medical Association, state and county medical societies, The American College of Surgeons, The Pan-Pacific Surgical Association, The American Orthopaedic Association, The American Academy of Orthopaedic Surgeons, The International Society of Orthopaedic Surgery and Traumatology, the Western Orthopedic Association, and the Orthopaedic Forum.

His contributions to and his work in these various professional organizations to which he belonged were many and continuous. His colleagues honored him and the organizations by electing him to the Presidency of The American Orthopaedic Association and also to the Presidency of the Western Orthopedic Association, both in the same year, 1955.

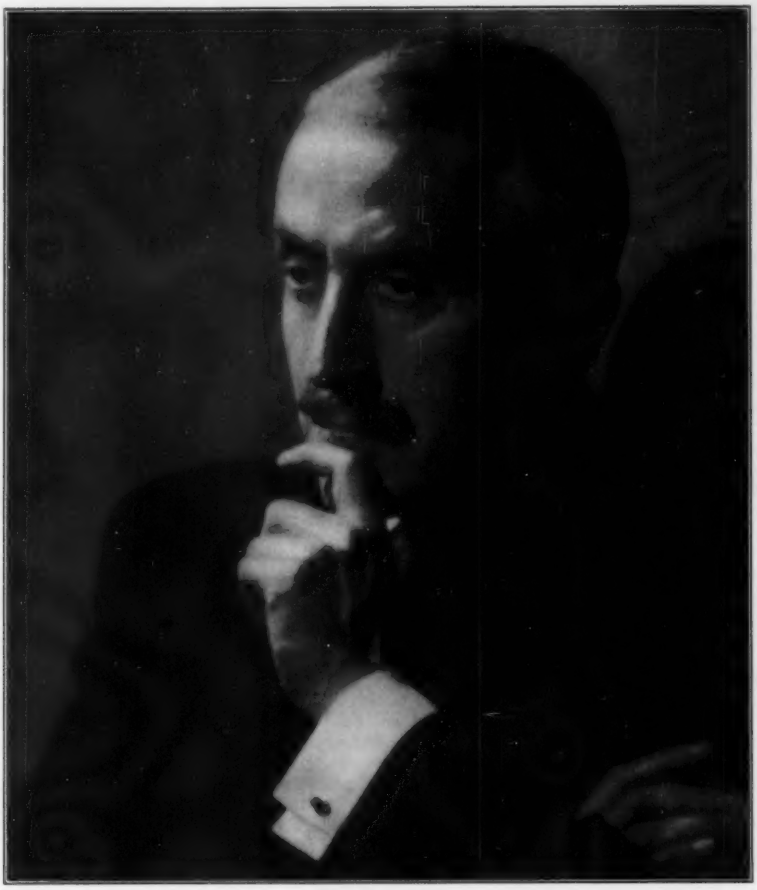
Warren White's contributions to orthopaedic literature were many and of great interest and value. He was particularly interested in the problem of equalization of leg length—writing first on tibial lengthening, then femoral shortening, epiphyseal-growth arrest, and a method of recording leg-length discrepancies. His writings ranged through the field of fractures and other traumata, and covered many and varied aspects of orthopaedic surgery. The great majority of these papers afforded ideas and suggestions which are of help to his colleagues.

Warren White was an excellent teacher, and his residency training was eagerly sought and profitably pursued, as his pupils are bearing witness.

In 1917 Warren White married Helen Angell, who was an ideal wife and helpmate for forty-two years. They made a wonderful team. Mrs. White and two sons, Warren White, Jr., and Gilbert White, survive him.

In affectionate admiration we bid farewell to a beloved friend.

M. C.



JULIUS HASS
1885 – 1959

The death of Professor Julius Hass on August 17, 1959, brought to a close a life full of distinguished service in orthopaedic surgery. Owing to the fact that his professional career was divided into two periods, the Austrian and the American, the former being considerably longer than the latter, it would be necessary to have two biographers, one from each country, to do full justice to the importance of his various contributions. I knew him only in the American period.

Julius Hass was born in Vienna and lived and worked there until 1938, when, following the German Anschluss, and at the peak of professional eminence, he became a victim of Nazi persecution. He determined to abandon his great career and to move to the United States and make a new home for himself and his wife and one son. He settled in New York City. This decision took great courage because it is always hard to start all over again in a foreign country, especially so for one who had already reached middle age. He had also to leave behind his invaluable records. That he was again able to climb to the summit in professional regard is proof of his indomitable industry, his high professional competence, and his integrity.

Hass received his degree in medicine from the University of Vienna in 1910. He interned at the Allgemeines Krankenhaus in Vienna, followed by an appointment as surgical assistant on the service of Professor Frank. At the same time he attended the Roentgen Institute of Dr. Holzknecht where he became acquainted with the fundamentals of bone and joint roentgenology. These studies stimulated Hass's decision to specialize in orthopaedic surgery. In 1912 he was appointed to the position of assistant (Hilfsartz) at the Universitäts-Ambulatorium und Abteilung für orthopädische Chirurgie, which was the official title of the Lorenz Clinic. This became his working place for more than a quarter of a century.

His diligence, ambition, knowledge, and surgical skill made him very soon the favorite

pupil of his teacher, the great Professor Adolph Lorenz, whose associate and co-worker he subsequently became.

In a recent memorial tribute, Dr. Albert Lorenz, the son of Professor Lorenz, wrote that Hass was the last outstanding pupil of Lorenz; he always advocated Lorenz's principles of conservative orthopaedic surgery that were based on the motto: *Primum non nocere*. In 1920 Hass received the *venia legendi* as Dozent for orthopaedic surgery, and in 1929 he succeeded Lorenz with the title of Professor Extraordinarius für Orthopädische Chirurgie.

The scientific papers which Hass published in Europe were on the one hand based on the teachings of Adolph Lorenz; in these publications Hass defined, defended, enlarged, and modified with his own observations and experiences the Lorenz principles of orthopaedic surgery. On the other hand, Hass independently presented new and pioneering contributions of his own to orthopaedic surgery, among which were:

1. Tendon transplantation for injuries to the radial nerve. This method, still used in Vienna, consisted in transplanting the flexor carpi ulnaris to the extensor digitorum communis, and the flexor carpi radialis to the extensor pollicis brevis and abductor pollicis longus.

2. An arthroplasty for mobilizing ankylosed elbows and knees. This consisted in reshaping of the distal ends of the humerus and femur into bone wedges which articulated with saucerized surfaces in the distal bones. He used fatty and fascial tissue for interposition.

3. His textbook on conservative and operative orthopaedics, which was his most important publication. Physicians frequently regret that Lorenz did not write a textbook on orthopaedic surgery based on his own concepts and principles; Hass did this for him in writing his book.

Hass was a brilliant speaker and commanded a masterly knowledge of the German language, which, in connection with a pleasant voice that was easily heard, made him an ideal teacher. He had the gift of clear communication with his audience, and his listeners enjoyed his lectures with enthusiasm.

When Hass arrived in New York City in 1939 he had lost both his professional position and his life savings. For some time he had to sit on the side lines while struggling to pass the State Medical Licensing Board examinations, a terrible task for a man of his seniority. He utilized part of this time in writing medical papers and in getting acquainted with his new environment. He was a constant visitor to the Hospital for Special Surgery where the orthopaedic residents and medical staff members quickly learned to make use of his interest and knowledge of congenital dislocation of the hip for their own benefit. In 1941, when he was licensed to practice, he was appointed Chief of the Orthopaedic Department at the Montefiore Hospital. He served there until 1947 when he had to retire because of age limitations and became consultant to the Hospital. He was also appointed Consultant to the Hospital for Special Surgery where he treated most of his private patients who needed hospital care. He was constantly helpful in the treatment of congenital dislocation of the hip and in teaching the residents. Everyone learned to know and respect this quiet-voiced man in whose mind was compressed such wide experience and rich knowledge.

After coming to the United States Hass made the following important contributions:

1. A type of subtrochanteric osteotomy which forced the lesser trochanter of the femur into the acetabulum as a means of articulation and pelvic support. This procedure is valuable and is generally designated by the author's name.

2. A book on congenital dislocation of the hip which summarized his experience in the treatment of over 2,000 patients and surveyed the progress made in the treatment of this condition in a period extending over fifty years. This is the most authoritative review ever written and is bound to occupy an important place in the literature of the subject for years to come. He supplemented this with additional articles on special aspects of the same subject.

3. Finally, an article written in conjunction with a graduate of the Hospital for Special Surgery, Robert Hass (no relation), describing a remarkable condition of joint instability and recurrent dislocation which had not hitherto been described.

In 1957 the King Umberto Prize of the Instituto Rizzoli of Bologna, Italy, was awarded to Julius Hass on the basis of his book, *Congenital Dislocation of the Hip*. This prize is given once every five years for the best orthopaedic work published during the period. The award and the gold medal which accompanied it were presented to Hass by the Italian Consul General on the occasion of a special meeting in Hass's honor which was held at the Hospital for Special Surgery. This was also an opportunity for his friends and colleagues to show their esteem and regard, which a large number of them did.

Julius Hass had other pleasant memories to look back on besides his professional ones. He had one other passion in addition to orthopaedic surgery and that was hunting. In the former days in Austria he always made a trip to the Carpathian Mountains region, or other areas, every year to chase deer. He was a keen shot and an indefatigable pursuer. His chase often led him long distances over mountain slopes and through snow fields until he caught up with and bagged his prey. Many trophies of his skill decorated the walls of his home, and he had much pleasure in showing them to his guests and in talking about his hunting trips.

The height of the worldly success was attained through connections he made with various Indian rajahs and princes, beginning in 1932 when the nephew of the Nizam of Hyderabad, and former premier of that country, came to Vienna seeking relief from a disability of the

elbow. Julius Hass operated on him with a successful result. Adolph Lorenz wrote about this in his autobiography, *My Life and Work*, as follows: "I am afraid that my excellent pupil knew better how to perform the operation than to ask a fee worthy of the occasion, which would have freed him from care for the rest of his life." At any rate, this operation established Hass as the surgeon to be seen by any Indian prince who was suffering from an orthopaedic disability. In 1934 he was invited to make a trip to India and while there he operated on several maharajas and Indian princes. He returned to India in 1938 after leaving Austria, and at that time an offer was made to build an orthopaedic hospital after his own plans if he would stay to head it. Hass did not feel able to adjust his life and that of his family to the customs and climate of India and declined the offer. It is needless to say that both trips offered Hass the opportunity of indulging his favorite pastime of hunting. He shot tigers and other big game from elephants and from lures and brought back to the United States skins and other trophies.

Julius took great pride in his family and was a charming host. Although he could talk about many things, his overwhelming interest was orthopaedic surgery. He is survived by an only son, Anthony, a graduate of the Princeton School of Engineering who works in Washington and has two children. Throughout his life, Julius Hass was assisted and strongly supported in all he undertook by his surviving widow, Lisl, a very charming and energetic woman.

P. D. W.

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News Notes

The Annual Meeting of **The American Orthopaedic Association** will be held at The Homestead, Hot Springs, Virginia, May 30 through June 2, 1960.

The **Exchange Fellowship Committee** of **The American Orthopaedic Association** is now inviting applications from American orthopaedic surgeons who are interested in the tour to Great Britain in the Spring of 1961. The requirements are: The applicant must be under forty years of age as of December 1, 1960; he must have completed Part 2 of the American Board of Orthopaedic Surgery examinations; and he must be a citizen of the United States. Requests for application blanks should be made to the Chairman of the Exchange Fellowship Committee, Dr. J. Neill Garber, 806 Hume Mansur Building, Indianapolis, Indiana.

The itinerary for the **Exchange Fellows** who are coming from **Great Britain** in April includes visits to orthopaedic centers at Ann Arbor, Michigan; Chicago, Illinois; Rochester, Minnesota; Edmonton, Alberta, Canada; Vancouver, British Columbia, Canada; Seattle, Washington; Portland, Oregon; Los Angeles, California; San Antonio, Houston, and Galveston, Texas; Memphis, Tennessee; and Chapel Hill and Durham, North Carolina. They have been invited to attend the Annual Meeting of The American Orthopaedic Association at Hot Springs, Virginia. Their tour concludes with visits to Washington, D. C., and New York City.

The Exchange Fellows who are coming from Great Britain are:

J. W. Dickson, F.R.C.S., Ipswich, Suffolk;
W. G. Doig, F.R.C.S., Melbourne, Australia;
A. H. C. Ratcliff, F.R.C.S., Southend-on-Sea, Essex;
R. H. C. Robins, F.R.C.S., Exeter, Devon;
J. H. S. Scott, F.R.C.S. (Edin.), Edinburgh, Scotland.

The **Association of Bone and Joint Surgeons** is sponsoring the Nicholas Andry Essay Award. This award is for an original essay on a subject related to orthopaedics—basic research, clinical research, clinical orthopaedics, or case reports. In general, the award is to be based upon the quality of the material rather than the quantity, but there is no specific limitation as to the length of the essay. The manuscript should be submitted in three copies by February 1 of each year to Dr. William Minor Deyerle, *Secretary*, Association of Bone and Joint Surgeons, 2222 Monument Avenue, Richmond 20, Virginia.

Those eligible to compete for the award must have taken the first part of the orthopaedic board examinations and have completed formal orthopaedic training; must be eligible to take the second part of the orthopaedic board examinations at the completion of the practice-period requirement (he need not, however, have completed his practice period before submitting the essay). The period of eligibility expires five years after the passing of the second part of the board examinations or seven years after the completion of formal training for the American Board of Orthopaedic Surgery.

The award consists of the following:

1. An honorarium of $500.00;
2. The essay is to be presented by the author at the next meeting of the Association of Bone and Joint Surgeons;
3. Up to $200.00 is to be provided for transportation to and from the meeting place of the Association;
4. The Paper is to be published in *Clinical Orthopaedics* and will be designated as a paper which received the Nicholas Andry Award;
5. A plaque inscribed with the author's name and subject will be presented.

The award is to be made by a committee of the Association composed of Dr. William Minor Deyerle, *Chairman*, Dr. Beckett Howorth, and Dr. Charles W. Goff.

For further information, write Dr. William Minor Deyerle, 2222 Monument Avenue, Richmond 20, Virginia.

The Meeting of the **Mid-Central States Orthopaedic Society** will be held in Wichita, Kansas, on April 8 and 9, 1960, at the Lassen Hotel and the Kansas Gas and Electric Building. The following program has been planned:

Friday Morning, April 8

End-Result Studies of Forearm Fractures Reduced with Malalignment in Children. Dr. Ward McClanahan, Wichita.

Scoliosis with Case Presentation. Dr. William R. Miller, Wichita.
Ostectomy of the Spine for Correction of Severe Scoliosis. Case Report. Dr. Lynn Litton, Kansas City.
Treatment of Congenital Pseudarthrosis of Tibia with Case Presentation. Dr. M. E. Pusitz, Topeka.
Multiple Pin Fixation of Femoral-Neck Fractures. Dr. D. S. McCrae, Salina.

Friday Afternoon, April 8

Traumatic Subtalar Dislocation. Dr. John F. Thurlow, Hays.
Neonatal Peroneal Palsy with Case Presentation. Patellectomy with Case Presentation. Dr. H. S. Bowman, Wichita.
Bone Stimulation Procedures in Children. Dr. Harry G. Kroll, Topeka.
Heyman Procedure for Adducted Forefeet. Dr. H. O. Marsh, Wichita.
The Use of the Bosworth Screw in Acromioclavicular Separation. Case Presentation. Resection of the Ulna. Dr. J. F. Lance, Wichita.

Saturday Morning, April 9

The Use of Plaster-of-Paris to Fill Defects in Bone. Dr. L. F. Peltier, Kansas City.
The Use of the Split Hansen-Street Nail in Fractures of the Femur (Three Cases). Dr. C. K. Wier, Wichita.
Fractures about the Knee Treated with Internal Fixation with Immediate Mobilization. Dr. Charles Rombold, Wichita.
End Result of Mitchell Procedure for Bunions. Dr. H. O. Anderson, Wichita.

THE GORDON RESEARCH CONFERENCES

The Gordon Research Conferences for 1960 will be held from 13 June to 2 September at Colby Junior College, New London, New Hampshire; New Hampton School, New Hampton, New Hampshire; and Kimball Union Academy, Meriden, New Hampshire.

Purpose: The conferences were established to stimulate research in universities, research foundations, and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of scheduled lectures and discussion groups. Sufficient time is available to stimulate informal discussions among the members of each conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. The afternoons are available for recreation, reading, or participation in discussion groups as the individual desires. This type of meeting is a valuable means of disseminating information and ideas to an extent that could not be achieved through the usual channels of publication and presentation at scientific meetings. In addition, scientists in related fields become acquainted, and valuable associations are formed that often result in collaboration and cooperative efforts between different laboratories.

It is hoped that each conference will extend the frontiers of science by fostering a free and informal exchange of ideas among persons actively interested in the subjects under discussion. The purpose of the program is to bring experts up to date on the latest developments, to analyze the significance of these developments, and to provoke suggestions concerning the underlying theories and profitable methods of approach for making progress. It is not to review the known fields of chemistry and physics.

In order to protect individual rights and to promote discussion, it is an established requirement of each conference that no information presented is to be used without specific authorization of the individual making the contribution, whether in formal presentation or in discussion. Scientific publications are not prepared as emanating from the conferences.

Registration and reservations: Attendance at the Conferences is by application. Individuals interested in attending the conferences are requested to send their applications to the Director at least two months prior to the date of the Conference. All applications must be submitted on the standard application form which may be obtained by writing to the office of the Director. This procedure is important because certain specific information is required in order that a fair and equitable decision on the application may be made. Attendance at each Conference is limited to approximately 100 conferees.

The Director will submit the names of those requesting authorization to attend the Conference Committee for each conference. This committee will review the names and select the members in an effort to distribute the attendance as widely as possible among the various institutions and laboratories represented by the applications. A registration card will be mailed as soon as possible to those selected. Advance registration by mail for each conference is required and registration is completed on receipt of the card and a deposit of $15. (Checks are to be made payable to the Gordon Research Conferences.) The deposit of $15. will be credited against the fixed fee for the Conference if the individual attends the Conference for which he has applied. A registration card not accompanied by the $15. deposit will not be accepted.

The Board of Trustees of the Conferences has established a fixed fee of $100. for resident conferees at each Conference. This fee was established to encourage attendance for the entire

Conference and to increase the Special Fund that is available to each Conference Chairman for the purpose of assisting conferees who attend a Conference at total or partial personal expense with their travel or subsistence expenses or with both. This fixed fee will be charged regardless of the time a conferee attends the Conference—that is, for periods of from one to four and one-half days. It is divided as follows: registration fee $40. ($15. for administration and $25. for the Special Fund); room and meals $60. (including gratuities), for five days. An additional charge of $1. per night per person will be made for a room with private bath or for a single room, of which there are only a limited number. These rooms will be assigned in the order that applications are received. An additional charge will also be made for rooms occupied more than five nights.

Members attending a Conference are expected to live at the Conference location because one of the objectives of the Conference is to provide a place where scientists can get together informally for discussion of scientific research of mutual interest. It is to the advantage of all participants to attend a Conference for the entire week. When special circumstances warrant a request to live elsewhere permission must be obtained from the Director. If the request is approved these non-resident conferees will be charged a registration fee of $50.

The fixed fee will cover registration, room (except room with private bath or single room), meals and gratuities for resident conferees. It will not provide for golf, telephone, taxi, laundry, conference photograph, or any other personal expenses.

Conferees living at the Conference location who will pay all or part of the fixed fee as a personal expense may request a reduction of $25. (the amount allotted for special fund) in the fixed fee. Application for this special fee ($75.) must be made when the registration card is returned to the Director.

Accommodations are available for wives who wish to accompany their husbands. All such requests should be made at the time the attendance application is submitted because these accommodations, limited in number, will be assigned in the order that specific requests are received. Children twelve years of age and over can be accommodated at the Conferences. Pets are not permitted in the dormitories.

Special fund: A special fund is provided for by the Board of Trustees from the registration fee. It is made available to the chairman of each conference for the purpose of increasing the participation of research scientists who could not otherwise attend because of financial limitations. Its use is not limited to scientists who have been invited by the chairman to attend a conference in order to present research results. The money is to be used as an assistance fund only and may be used to contribute toward traveling expenses or subsistence expenses at the conference, or both. Total travel and subsistence expenses will not usually be provided.

Cancellations: The cancellation of an approved application for attendance at a conference will cause forfeiture of the $15. deposit.

Attendance: Requests for attendance at the conferences, or for additional information, should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From 13 June to 2 September 1960 mail should be addressed to Colby Junior College, New London, New Hampshire.

GORDON RESEARCH CONFERENCES

CHEMISTRY, PHYSIOLOGY, AND STRUCTURE OF BONES AND TEETH

11-15 July 1960
Kimball Union Academy
Meriden, New Hampshire

B. B. Migicovsky, *Chairman*
W. P. Norris, *Vice-Chairman*

11 July

Selected Communications.

Clayton Rich, *Chairman*

W. P. L. Myers and W. Lawrence, Jr.: Studies on the Influence of Cortisone on Serum Calcium Homeostasis.

C. A. L. Bassett: Factors Contributing to Osteogenesis *in vitro*.

T. W. Speckman and W. P. Norris: Variations in Retention Kinetics of Bone Seeking Isotopes.

J. Samachson and H. Spencer: Comparison of Single and Multiple Doses of Sr^{85} and Ca^{45} in Man.

J. M. Jones, P. J. Kelly, and L. F. A. Peterson: The Effect of Beryllium on Bone, a Morphologic Study of the Progressive Changes in Rabbit Bone.

Bone Induction.

Leroy Lavine, *Chairman*

J. S. Nicholas: Induction and Its Relationship to Bone Structure.

M. Moss: Osteogenic Induction Factors.

12 July

J. J. Pritchard: Recruitment of Osteoblasts Relating to Bone Induction.

Hans Selye: Induction of Bone by Tissue Scaffoldings.

Nature and Mechanism of Hard Tissue Destruction.

Reidar F. Sognnaes, *Chairman*

N. M. Hancox: The Osteoclast.

13 July

Charles M. Dowse and William Neuman: Metabolism of Bone Cells.

George Nichols, Jr., Nancy Nichols, Andre B. Borle, Stein Schartum, and Gilbert Vaes: Cellular Metabolism of Bone.

Paul Goldhaber: Further Observations on Experimental Bone Resorption in Tissue Culture.

Organic Matrix in Calcification.

M. J. Glimcher, *Chairman*

F. Pautard: The Nature of the Organic Matrix and Its Role in the Development of Calcified Structures.

14 July

L. Johnson: Histochemical Changes in Organic Matrix Accompanying Calcification.

A. Sobel: Role of the Organic Matrix in the Nucleation and Growth of Bone Crystals.

Calcium Metabolism.

F. McLean, *Chairman*

J. Vincent: Metabolic Bone at the Histological Level.

15 July

Calcium Metabolism

H. F. DeLuca, *Chairman*

A. M. Shanes: Movement of Calcium in Non-skeletal Tissues.

M. R. Urist: Calcium and Protein Relations in the Blood.

R. H. Wasserman: Passage of Calcium across Biological Membranes.

The Forty-fourth Annual Meeting of the **Italian Orthopaedic Association** was held in Rome on October 23 through 25, 1959, under the Presidency of Professor Marino-Zuco. The main subject, New Aspects of Traumatology in Modern Life, was divided into five parts: the first dealt with statistical data and was opened by Professor L. Giuntini (Genoa); the second, dealing with bone lesions, was opened by Professor C. Camurati (Bologna); the third, on skin repair, was opened by Professor A. Bonola (Modena); the fourth, on vascular and nerve injuries, was opened by Professor G. F. Fineschi (Florence); the fifth, which dealt with social aspects and rehabilitation, was opened by Professor M. Paltrinieri (Pisa). The subjects were accurately reviewed by the speakers, Italian members and foreign guests taking part in the discussions. The next meeting will be held in Florence in the Fall of 1960 under the Presidency of Professor O. Scaglietti. The main subject to be discussed at this meeting will be Modern Treatment of Osteo-articular Tuberculosis.

The **Orthopaedic Guild** met on Friday and Saturday, October 30 and 31, 1959, in Hartford and New Haven, Connecticut. Dr. Charles W. Goff was the host and had arranged for a very constructive day of scientific papers and discussions in Hartford on Friday and at the Yale Medical School on Saturday morning.

The **Czechoslovak Association of Plastic Surgeons** will organize, from June 28 to June 30, 1960, in Mariánské Lázně (Czechoslovakia), the Second International Symposium of Plastic Surgery. The issues to be discussed are the transplantation of tissues and burns. Detailed information may be obtained from Dr. Richard Kluzák, Secretary of the Symposium, Clinic of Plastic Surgery, Šrobárova 50, Praha 12, Czechoslovakia.

The **Serbian Medical Society** has founded its first Section of Orthopaedics and Traumatology, electing Professor S. W. Stoianovitch, Director of Orthopaedic Clinic in Belgrade, President. The General Secretary is Dr. C. Rakitch.

The Twenty-seventh Annual Meeting of the **Clinical Orthopaedic Society** was held in Memphis, Tennessee, on October 22, 23, and 24, 1959, under the Presidency of Dr. Atha Thomas, Denver, Colorado. The officers for 1960 are:

President: Dr. Fred Reynolds, St. Louis, Missouri;
Vice-President: Dr. David J. Ansfield, Milwaukee, Wisconsin;
Secretary-Treasurer: Dr. Charles H. Frantz, Grand Rapids, Michigan.

The **North Carolina Orthopaedic Association** met on October 16 and 17, 1959, at Chapel Hill, North Carolina, under the Presidency of Dr. Stanley Atkins, Asheville. Officers for 1960 are:

President: Dr. J. Leonard Goldner, Durham;
Vice-President: Dr. Thomas B. Dameron, Jr., Raleigh;
Secretary-Treasurer: Dr. F. Wayne Lee, Charlotte.

The Fall Meeting of the **Oklahoma Orthopaedic Society** was held on October 25, 1959, in Oklahoma City, Oklahoma. Dr. H. Relton McCarroll of St. Louis, Missouri, was the guest-discussor. Dr. Ronald Garst, an orthopaedic missionary to India, was a welcome guest. The scientific program consisted of the presentation of problem cases for round-table discussion and comments by Dr. McCarroll. The old adage "misery loves company" proved to be true as always. The Oklahoma Orthopaedic Society voted unanimously to donate $100.00 yearly to the Orthopaedic Research Foundation and collective efforts will be made to secure a $100.00 donation by the entire membership of the Society on a yearly basis. The meeting closed with the first legal cocktail party that the Society has ever had. The members were no worse off than usual as the result of the availability of the spirits.

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(*Continued from page 332*)

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Book Reviews

THERAPEUTIC ELECTRICITY AND ULTRAVIOLET RADIATION. Edited by Sidney Licht, M.D. New Haven, Elizabeth Licht, Publisher, 1959. $10.00.

The subject of electrotherapy is one which has, of recent years, had a decline in interest by the medical profession. This is because of the advances in medical science that have discouraged the use of empirical methods, such as electrotherapy, in the treatment of a great many conditions. Ths history of this special form of treatment, however, is of interest and is well depicted by the editor, who is probably the outstanding historian in the field of physical medicine at this time.

The volume is really written for the specialist in physical medicine, or physiatrist; it is an essential textbook for residents training in this field. Successful attempts have been made to keep the subject matter on a scientific level, including much discussion by physicists and engineers, which would not be of interest to the general practitioner or the orthopaedic surgeon. On the clinical side, however, a chapter is devoted to electro-sleep therapy, which is almost unknown in this country. The subjects of diathermy—short-wave, microwave, and ultrasound—are omitted as their effects are primarily those of deep heat. Emphasis is placed, on the other hand, on electrical muscle stimulation and iontophoresis, or common ion transfer of molecules through the skin by continuous currents.

The second section of the book is devoted to ultraviolet radiation. The excellent historical section illustrates how much this was an important part of the practice of physical medicine during former years. The sections on the physics of ultraviolet radiation and the physiological effects omit controversial subjects and deal with the basic physics and physiology as now known. Editorial comments on the clinical value of radiation might be useful if they were added to these sections. In fact, in chief criticism of this volume, one might say that an editorial chapter summarizing the clinical value of electrotherapy and ultraviolet radiation therapy, as now understood, would add to the value of the book for the general practitioner, the orthopaedic surgeon, and the physical-therapy technician. In this chapter, a few more details of technique, including illustrations, would be highly acceptable.

Arthur L. Watkins, M.D.

TUMEURS BÉNIGNES DES OS ET DYSTROPHIES PSEUDO-TUMORALES. André Trifau, Henri Bureau, and Henri Payan. Paris, Masson et Cie, 1959. 4,200 fr.

In the preface to this handsome volume on benign, localized affections of bone, it is stated that the authors fill a void in the literature on the diseases of bone and not only review the literature but present their own observations based on extensive clinical experience. Presumably, the void existed primarily in the French literature, for several recent publications in English cover the subject adequately. The material presented, for the most part, is a straightforward review of current concepts. The classification of Lichtenstein is used, and most of the worthwhile references up to 1957 are included. This reviewer found several points with which he disagrees with the authors, not only with regard to their espousal of contested points of view, but also with regard to conclusions from their own experience. With reference to the benign giant-cell tumor, the only tumor described for which the data of the authors are presented in full, a questionable concept is advanced. The authors say that there are phases of evolution of some giant-cell tumors during which conservative therapy is warranted for perhaps a few months, until a stage of stability is reached. They state that this will allow a significantly lower incidence of recurrence after surgical treatment. This reviewer believes that such a concept is dangerous in that it presupposes the certainty that the giant-cell tumor in question is benign and avoids the thorny problem of differentiating histologically the benign from the malignant lesions. It is indeed strange that this same concept of the stability or evolutionary phase of lesions is not mentioned with respect to bone cysts, where it is generally accepted that this situation does indeed prevail and where no question of malignancy is raised when a recurrence is encountered. The statistics which the authors give concerning their giant-cell-tumor series are somewhat at variance with those of other published series and with the experience of this reviewer. Entirely too many of the lesions they discuss are found in very young children; the question of diagnosis must be raised with respect to the unusual age incidence of this tumor in their series.

The book is fairly well illustrated with regard to roentgenograms but very poorly illustrated and poorly documented with respect to the histological details of the individual lesions. Much emphasis is placed on the clinical findings and on the surgical treatment so that as a reference book for histology or comprehensive therapy it is incomplete. Altogether this volume will have its greatest appeal among French students and clinicians. Those who are capable of reading English with facility will prefer more authoritative, recent treatises which are superior, particularly for purposes of reference.

Jonathan Cohen, M.D.

PRINCIPLES OF RADIATION DOSIMETRY. G. N. Whyte. New York, John Wiley and Sons, Inc., 1959. $7.00.

This book encompasses a somewhat narrower area than indicated by the title. In its essence it is a treatise on the principles governing the evaluation of exposure dose and absorbed dose from ionizing radiation by ionization measurements in air. It is taken for granted that ionization in gases represents dosimetry. Within this limited sphere the book gives a compact, yet comprehensive, treatment of current physical thinking.

The reader will find, however, only the sketchiest references to other methods of radiation dosimetry of growing importance, such as chemical dosimeters, phosphate glass, photographic film, and counter methods. Moreover, there is little discussion, as the title would indicate, of practical use and design of radiation dosimetric equipment. For most of this other material, one is referred to the compendious work, *Radiation Dosimetry,* published in 1956, and edited by Hine and Brownell, which remains the most comprehensive book in this area. Indeed, the only new part of Whyte's book in comparison with its forerunner is the clear distinction it makes between exposure dose in roentgens and absorbed dose in rads, which has recently been introduced into radiology and which is discussed in Handbook 62 of the National Bureau of Standards. Exposure-dose measurement by cavity chambers is particularly well treated. The subject of stopping-power ratio between wall material and air is covered in considerable detail, reflecting my own published work in this field. This section follows as a logical sequel to the well chosen discussion of charged-particle absorption in an earlier chapter including the effects of polarized atoms (the density effect).

This book is, obviously, written for the would-be specialist in radiological physics; the mode of expression is largely mathematical. Its subject is rather specialized for the average physicist, and the medical man without a knowledge of mathematics would gain little from it. The physical point of view is emphasized by the lack of commentary on "biological" dosimetry —the relation of biological effect to the physical deposition of energy, of great interest to the clinician. Thus, in the opening chapter the linear distribution of ionization along an ionized track, which is related to biological effectiveness, is not listed as a variable of importance.

This book also lacks philosophy, criticism of the basic nature of the present units, making no mention of current international movements to change them and their meaning. The limitations of the roentgen for high-energy radiation are not discussed.

In summary, the book is a competent, well written but conventional treatment of radiation dosimetry.

Edward W. Webster, Ph.D.

TOTAL SURGICAL MANAGEMENT. James D. Hardy, M.D. New York, Grune and Stratton, Inc., 1959. $9.50.

This small volume is a brief, well written work which attempts to hit the practical high spots in over-all surgical management.

The twenty-four chapters are organized into three approximately equal sections which deal with preoperative, transoperative, and postoperative care.

The first section of preoperative care consists of eight chapters which review and discuss operability, fluid management, shock, abnormal bleeding, wound management, and trauma, in a lucid fashion. These chapters will provide an excellent introduction to surgery for the clinical clerk and intern and an excellent review for the general practitioner and specialist.

The second section consists of ten chapters in which specific operative procedures are detailed. An attempt is made to cover thoracic, vascular, gastro-intestinal, biliary, and endocrine surgery. The inclusion of diagnosis, operative technique, complications, and preoperative and postoperative care of so extensive a field in 134 pages results in incomplete and inadequate discussion. The illustrations in this section also leave a good deal to be desired.

The third section of the volume consists of six chapters with valuable suggestions and outlines regarding the care of infants, in addition to neurosurgery, urology, gynecology, anesthesia, the recovery room, and common postoperative problems. This portion is up to the quality of the first section.

George L. Nardi, M.D.

THERAPEUTIC RADIOLOGY. William T. Moss, M.D. St. Louis, The C. V. Mosby Co., 1959. $12.50.

This is a first-class textbook for physicians being trained in therapeutic radiology. It is not, and it was not the author's intent that it should be, a cookbook which the physician can open and find, spelled out for him, a procedure by which cancer can be cured by x-ray. Rather, it is an exposition of a clinical approach to cancer management with ionizing radiation as the tool.

Special emphasis is placed on the natural history of cancer and what can be expected of radiotherapy as a means of dealing with it. The author also discusses the general management of patients undergoing radiotherapy.

Although the technical aspects of radiotherapeutic procedures are given no more than their just due, they are sufficient as a guide to the student who has clinical opportunity to enlarge on them, and as a reference for others.

The book is divided into twenty chapters, the first of which is an introduction to the philosophy and general principles of radiotherapy and the physical and biological concepts on which they are based.

In the remaining nineteen chapters—system by system—most of the more common situations in which radiotherapy plays—or in which it has been hoped it might play—a part are presented. Each chapter starts with a review of the radio-responsiveness of the abnormal and normal tissues under consideration. Then follows a discussion of the disease and its behavior and the indications for radiotherapy and other forms of management.

A general review of the technical aspects of the various procedures applicable to the situation under consideration and of the management of the patient undergoing treatment precedes a rather thorough-going examination of what general experience has been in the treatment of the disease in question. Personal, and sometimes rather dogmatic, observations are interspersed with the more general reviews, and controversy is not avoided, thus improving the pedagogical worth. A well considered summary and carefully selected bibliography complete each section.

This is a worthwhile textbook. Concise, well put together, and, aside from the errors to which any first edition is entitled and some personal hobbyhorses, authoritative. The organization is logical. The coverage, overlooking a tendency to underemphasize the use of radium and radium substitutes, is quite complete. Photographs and line drawings are clear and informative. The typography is good and the binding is attractive and probably as sturdy as most present-day hard-cover textbooks.

Students and physicians who want an introduction to basic facts about cancer management by this means will consider their money well spent. The man who only wants a formulary will not.

Milford D. Schulz, M.D.

Rehabilitation Center Planning. F. Cuthbert Salmon and Christine F. Salmon. University Park, The Pennsylvania State University Press, 1959. $12.50.

This profusely illustrated and graphic discussion of the specialty planning and administration problems concerned with rehabilitation centers is the result of a project conducted by Pennsylvania State University with its co-sponsors, the Conference of Rehabilitation Centers and the American Institute of Architects, and made possible through a grant from the United States Department of Health, Education and Welfare.

The text, in its plunging and yawing from abstract consideration of principles to details of plans and construction of equipment seems, at times, to lose its thread of continuity but never its sustenance of interest in the varied aspects of the problem. This may not be deliberate, but it does serve to drive home the warning of the authors that there is no solution of one problem that should be borrowed and used as a pat solution in another situation.

There is recognition that attainment of vocational rehabilitation is a main end desire of the process for the patient. This part of the guide is, justly, most comprehensive in its treatment.

The section devoted to children's treatment and training provides material for this specialty phase of a specialty architectural planning program.

The supplement shows in outline form, with cogent statistical information, the layouts of ten centers. Seven are out-patient facilities with case loads ranging from a low of 190 to a high of 4,514 per year. Three of the centers illustrated have in-patient accommodations, one being the huge 348-bed unit at Johnstown, Pennsylvania, with its extensive vocational training facilities.

Although, probably, of greatest use in providing an architect with a necessary background of the social and physical needs of a rehabilitation-center planning program, the guide will be of use to the entire staffs of centers, not only just embarking on planning preparations, but also for reviews by staffs of centers in actual operation.

Joseph W. Degen

Industrial Carcinogens. Robert E. Eckardt, M.D., New York, Grune and Stratton, Inc., 1959. $6.50.

This is one of the series of monographs designed to take up presently available knowledge in the field of industrial medicine. Dr. A. J. Lanza, long an authority in this field, is the editor. The author is eminently qualified for this work as a result of his experience in charge of medical research for a large petroleum firm.

This volume of 159 pages is easily read in a highly satisfactory format, and cannot be too highly recommended in these days of alarms about environmental causes of malignant growths, especially those of the lung. Chapter 3 describes what is presently accepted in the field of occupational cancers of the skin, the bladder, and the respiratory tract. However, to this reader the most important material is in Chapter 2 where experimental carcinogenesis is discussed. The pressures of military effort and industrial technical change make it difficult to judge what materials will and will not be hazardous both to workers and to exposed populations. Dr. Eckardt has made a real contribution in evaluating so clearly, in a fashion that can be under-

stood by what might be termed the medical layman, the use and limits of experimental study of cancer-producing agents.

The last two chapters entitled "Protective Programs" and "Medico-Legal Considerations" will be more specifically interesting to the medical officers, the industrial hygienists, and the safety engineers who must day by day work out the details of protective measures.

This is a good book and should be widely read.

Harriet L. Hardy, M.D.

DISORDERS OF THE TEMPOROMANDIBULAR JOINT. DIAGNOSIS, MANAGEMENT, RELATIONS TO OCCLUSION OF TEETH. Laszlo Schwartz, M.D. Philadelphia, W. B. Saunders Company, 1959. $15.00.

This book represents a study of more than 2,500 patients at the Temporomandibular Joint Clinic at the Columbia-Presbyterian Medical Center in New York City. It is written in a clear style and is beautifully illustrated with 458 excellent photographs and reproductions of roentgenograms.

The author's thesis is that the most common disorder of the temporomandibular joint is a pain-dysfunction syndrome, or myofascial pain syndrome. Incoordination of the mandibular muscles, possibly related to increased muscle tension, results in clicking, subluxation, and, even, dislocation. Painful limitation on mandibular movements, caused by spasm of some of the masticatory muscles, often follows. No single cause exists for the pain-dysfunction syndrome.

The book is divided into five major sections: General Considerations (including the role of occlusion of the teeth, functional anatomy of the temporomandibular joint, embryology, and malformations of the joint); Diagnostic Procedures (history and examination, radiography, and electromyography); Differential Diagnosis; Methods of Treatment; and Management of Disorders.

The chapter devoted to History and Physical Examination is particularly useful, describing the various facets of investigation in a meticulous and lucid manner. The multiple illustrations demonstrate the details in exemplary fashion.

The author stresses a conservative approach in the treatment of the various disorders afflicting the temporomandibular joint. Although one may not agree entirely, it should be emphasized that conservative therapy is the treatment of choice in most cases, and certainly should be the preliminary method of therapy in all cases of derangement of this joint.

In his conclusions on the treatment of osteoarthritis of the temporomandibular joint, the author states that "management is palliative and since osteoarthritis is a local disorder, its management falls into realm of the dentist." The reviewer would differ with this viewpoint, since some patients having the most gratifying results have been those with unilateral osteoarthritis of the temporomandibular joint treated by unilateral condylectomy and meniscectomy.

The value of the book is further enhanced by the caliber and varied specialties of the numerous contributors who wrote the different chapters—dental surgeons, neurologists, a physiatrist, an internist, a neurosurgeon, a roentgenologist, an anesthetist, an otolaryngologist, and a psychiatrist.

The book is a significant addition to the literature concerning temporomandibular-joint disorders, and is recommended highly for its rational, conservative, and informative approach to this subject.

Caroll M. Silver, M.D.

EXPERIMENTAL SURGERY. INCLUDING SURGICAL PHYSIOLOGY. Ed. 4. J. Markowitz, J. Archibald, and H. G. Downie. Baltimore, The Williams and Wilkins Company, 1959. $12.50.

The Fourth Edition of Experimental Surgery, a book which was first published twenty-two years ago, attempts the tremendous task of covering nearly all anatomical and physiological areas of surgical experimentation. The only limitation of scope is to experimentation accomplished by technical procedures in the animal laboratory, principally the dog laboratory. Fortunately the authors do not try to encompass an even more nebulous area loosely called "research in surgery", which is of course nearly as broad as research itself. But the limitation is not great. The subtitle, "Including Surgical Physiology", indicates the encyclopedic extent of the text. Despite the general success achieved, the defects of a one-volume encyclopedia also follow: necessary incompleteness in some areas; serious problems of selections and exclusion of material; and, in the rapidly moving fields encompassed, the problem of being not quite up-to-date in certain areas.

After a chapter on the antivivisection movement, which is a very proper concern of the experimental surgeon, there follow excellent general chapters on animal care, anesthesia, basic equipment, and techniques. These chapters are directed to the level of the medical student or to the investigator who has had no experience with animal work. A subsequent chapter on surgical exercises is somewhat confusingly separated into a group of procedures "suitable for undergraduate and medical students" (parathyroidectomy, ureterovenous anastomosis, and adrenalectomy) and "therapeutic" procedures (an abbreviated manual of veterinary surgery). The descriptions are clear and useful but the reader may wonder to whom the chapter is directed.

The following 240 pages are devoted to the gastro-intestinal tract, pancreas, and biliary system. No assumptions are made about technical knowledge and the general procedures of alimentary canal surgery are clearly presented in detail. In describing experimental procedures on the upper intestinal tract of the dog, the authors review the classic experimental procedures, information so gained, and conclusions drawn. The good organization and wealth of detail furnish an excellent starting point for the investigator planning dog work in gastro-intestinal problems.

Although the book's approach is firstly from the standpoint of animal experimentation, it is manifestly impossible to approach the subject of experimental surgery without primary consideration of the objectives of the research. The objectives, after all, must dictate the techniques and not the reverse. In considering many of the problems of investigative work in animals, the authors face a basic problem of what properly belongs in this book. Where the procedures of experimental surgery are largely ablative or consist of collection of samples of body fluids or tissues, or the infliction of various types of controlled injury, emphasis must be increasingly placed on physiology, chemistry, and pathology rather than on experimental technique. Experimental pathology receives somewhat patchy treatment, being emphasized in some systems such as the respiratory, where the body of purely technical surgical procedures is somewhat smaller, and de-emphasized in other areas. Therefore, in reading the survey chapter on hematology, one wonders why not a chapter on immunology, metabolic disease, or renal physiology?

However, within these somewhat poorly defined and necessarily arbitrary limits, the treatment of material is by and large good. In sections such as those on peptic ulcer, where the available dog work is extensive, well defined, and technically interesting, the treatment is much more complete and useful than in areas where an attempt is made to review more diffuse information and experimentation. For example, the discussion of surgical physiology of intestinal obstruction is somewhat less than satisfactory.

There are chapters on respiratory, cardiac, autonomic, vascular, renal, hepatic, urological, and other types of surgery. There are also chapters on experimental surgery of joints and bones which may be of considerable interest to the readers of The Journal. These chapters briefly summarize some of the known facts about joint-and-bone formation and physiology. Here again the emphasis of a book such as this had to be on technique, which in experimentation in the musculoskeletal system consists largely of a manual on the use of orthopaedic instruments. In this region technical experimental surgery must make use of fairly standard techniques applied to a research problem, rather than the devising of preparations of general applicability.

In a sense we are pointing out the difficulties which the authors faced in attempting a volume of such wide coverage in such rapidly moving fields. It should therefore be emphasized that a remarkably comprehensive coverage has actually been effected, and there are many areas of technical investigative surgery where the authors' compilation of material will provide an excellent starting point for the investigator. Whether one agrees with the authors' thesis that experimental dog surgery is the best way to train young surgeons is another argument entirely. One might also wish for a modification of the somewhat polemical style of the introductory remarks.

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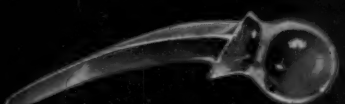

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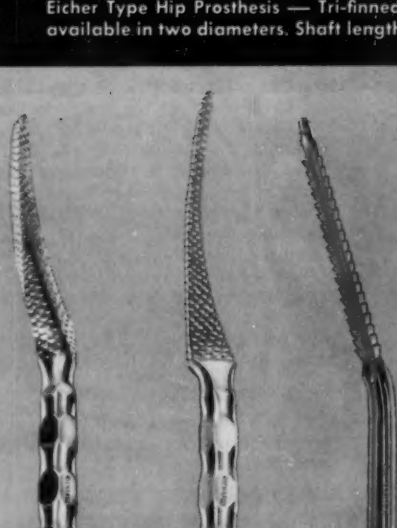

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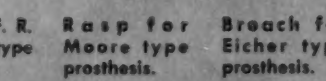

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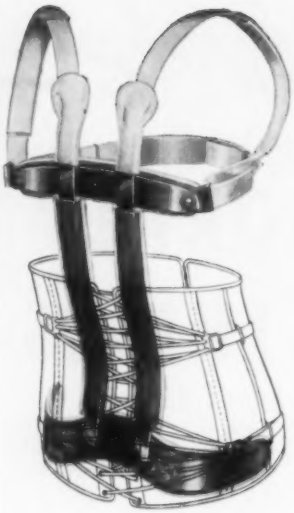

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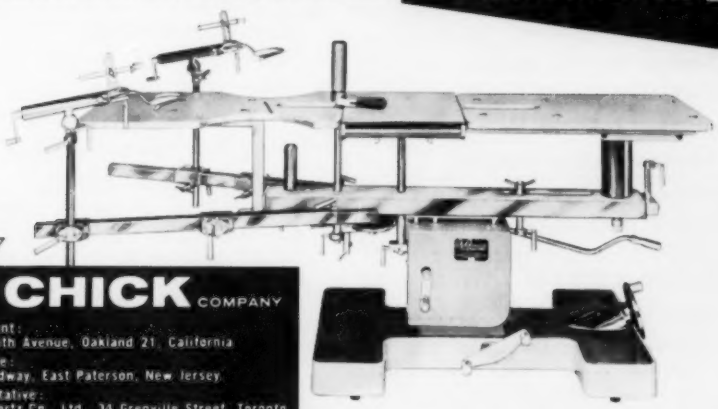

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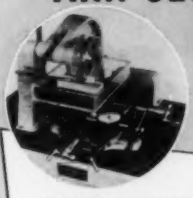

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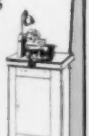

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